

AIRBORNE LOW-RANGE RADIO ALTIMETER EQUIPMENT

Notice of Proposed Rule Making

Notice is hereby given that the Federal Aviation Agency has under consideration a proposal to amend Part 37 [New] of the Federal Aviation Regulations by adding a new Technical Standard Order (TSO) for Airborne Low-Range Radio Altimeter Equipment. This TSO contains the minimum performance standards which such equipment must meet in order for the manufacturer to identify it with the applicable TSO marking.

Radio altimeters are being designed and developed at the present time and various operators have expressed an interest in such equipment. Therefore, the Agency considers it appropriate to provide a basis for the TSO-approval of these altimeters.

Interested persons are invited to participate in the making of the proposed rule by submitting such written data, views, or arguments as they may desire. Communications should identify the docket number and be submitted in duplicate to the Federal Aviation Agency, Office of the General Counsel, Attention: Rules Docket, 800 Independence Avenue, SW., Washington, D.C. 20553. All communications received on or before July 15, 1965 will be considered by the Administrator before taking action on the proposed rule. The proposal contained in this notice may be changed in the light of comments received. All comments submitted will be available, both before and after the closing date for comments, in the Rules Docket for examination by interested persons.

In consideration of the foregoing, it is proposed to amend Part 37 [New] of the Federal Aviation Regulations by adding a new § 37.193 to read as follows:

§ 37.193 Airborne Low-Range Radio Altimeters—TSO-C87.

(a) *Applicability.* This Technical Standard Order prescribes the minimum performance standards which airborne low-range radio altimeter equipment must meet in order to be identified with the applicable TSO marking. New models of the equipment which are to be so identified and which are manufactured on or after the effective date of this section must meet the requirements set forth in the Federal Aviation Agency standard entitled "Minimum Performance Standards For Airborne Low-Range Radio Altimeters" dated August 4, 1964.¹

(b) *Markings.*

(1) In addition to the markings specified in § 37.7, the equipment must be marked to indicate the environmental extremes over which it has been designed to operate. There are six environmental procedures outlined in the FAA document "Environmental Test Procedures for Airborne Electronic Equipment" which have categories established. These must be identified on the nameplate by the words "Environmental Categories" or, as abbreviated, "Env. Cat." followed by six letters which identify the categories designated in the FAA document. Reading from left to right, the category designations must appear on the nameplate in the following order so that they may be readily identified—

- (i) Temperature-altitude category;
- (ii) Vibration category;
- (iii) Audio-frequency magnetic field susceptibility category;

¹Copies may be obtained upon request addressed to Publishing and Graphics Division, Distribution Section, HQ-426, Federal Aviation Agency, Washington, D.C. 20553.

categories. In this case, the manufacturer must be marked with both categories in the space designated for that category by placing one letter above the other in the following manner: Env. Cat. ABAAAX.

D

(c) *Data requirements.* In accordance with § 37.5, the manufacturer must furnish to the Chief, Engineering and Manufacturing Branch, Flight Standards Division, Federal Aviation

(d) *Previously approved equipment.* Airborne low-range radio altimeter models approved prior to the effective date of this section may continue to be manufactured under the provisions of their original approval.

This amendment is proposed under the authority of Sections 313(a) and 601 of the Federal Aviation Act of 1958 (72 Stat. 752, 775; 49 U.S.C. 1354, 1421).



Acting Director,
Flight Standards Service

Issued in Washington, D.C. on March 25, 1965.

**MINIMUM PERFORMANCE STANDARDS FOR
AIRBORNE LOW-RANGE RADIO ALTIMETERS**

August 4, 1964

1.0	GENERAL STANDARDS	1
1.1	Rating of Components	1
1.2	Operation of Controls	1
1.3	Accessibility of Controls	1
1.4	Effects of Test	1
2.0	MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS	1
2.1	Accuracy of Pilot's Display	1
2.2	Accuracy of the Precision Equipment Output	1
2.3	Precision Equipment Output Noise	1
2.4	Time Constant	1
2.5	Rate Data	2
2.6	Failure Warning System	2
2.7	Self Test Feature	2
2.8	Transmitter Operating Frequency	2
3.0	MINIMUM PERFORMANCE STANDARDS UNDER ENVIRONMENTAL CONDITIONS	2
3.1	Temperature-Altitude	2
3.2	Humidity	3
3.3	Shock	3
3.4	Vibration	3
3.5	Temperature Variation	3
3.6	Power Input Variation	3
3.7	Low Voltage	3
3.8	Conducted Voltage Transient	3
3.9	Conducted Audio-Frequency Susceptibility	3
3.10	Audio-Frequency Magnetic Field Susceptibility	3
3.11	Radio-Frequency Susceptibility (Radiated and Conducted)	3
3.12	Explosion (When required)	3
3.13	Emission of Radio Frequency Energy	3
APPENDIX A		5
1.0	TEST CONDITIONS	5
1.1	Power Input Voltage—Direct Current	5
1.2	Power Input Voltage—Alternating Current	5
1.3	Adjustment of Equipment	5
1.4	Ambient Conditions	5
1.5	Warm-Up Period	5
1.6	Description of Test Equipment	5
2.0	TEST PROCEDURES	5
2.1	Accuracy (In-Flight)	5
2.2	Altitude Accuracy and Loop Gain	6
2.3	Altitude Noise	6

APPENDIX B—DETERMINATION OF EXTERNAL LOOP LOSS
(DERIVATION)

1.0	Definition of External Loop Loss	9
2.0	Characteristics of External Loop Loss	9
3.0	External Loop Loss, Beam Limited Case	9
4.0	External Loop Loss, Pulse Limited Case	9
5.0	Essentials of F or F(H)	9
6.0	Curves of External Loop Loss	9
	Figure 1	10
	Figure 2	11
	Figure 3	12
	Figure 4	13
	Figure 5	14
	Figure 6	15

FAA Document for "Environmental Test Procedures for Airborne Electronic Equipment"

This document sets forth the characteristics of the airborne low-range radio altimeter which are essential for its operation in applications which provide measured height above terrain for clearance and landing data. The potentially diverse range of applications for this equipment precludes the precise definition of the term "low-range". It should be recognized that very limited capabilities may suffice in some installations while other installations may require a broader range of altitude (height) data.

The term "altitude" shall be defined for the purpose of this standard as height or distance from the terrain to the altimeter antennas.

Compliance with these standards is required as a means of assuring that the equipment will satisfactorily perform its intended functions over all conditions normally encountered in routine aeronautical operations.

The word "equipment" as used herein includes all of the components or units necessary (as determined by the equipment manufacturer) for the equipment to perform properly its intended function. For example, radio altimeter "equipment" may include an antenna, a receiver-transmitter unit, a power supply, and indicator unit, a shock mount, etc. In the case of this example, all of the foregoing components or units comprise the "equipment". It should not be inferred from this example, however, that all radio altimeter equipment will necessarily include all of the foregoing components. This will depend on the design used by the equipment manufacturer.

Inasmuch as measured values of radio equipment performance characteristics may be a function of the method of measurement, standard test conditions and methods of tests are also included in this standard.

1.0 GENERAL STANDARDS.

1.1 Rating of Components. The equipment shall not incorporate any component of such rating that, when the equipment is operated throughout the range of the specified environmental tests, the rating established by the manufacturer of the component is exceeded. For electron tubes and transistors, either the tube or transistor manufacturer's continuous commercial service rating, his established pulse rating, or his approved rating as applied to the particular application, whichever is appropriate, shall apply, except for the heaters and filaments. The voltage applied to the heaters and filaments of electron tubes shall be within 5% of the manufacturer's rating, or at a value approved by the tube manufacturer for the particular service, when the equipment is operated under standard operating conditions. When the heaters and filaments are connected in series, the 5% tolerance shall apply to the sum of their voltage ratings.

1.2 Operation of Controls. The operation of controls intended for use during flight, at all possible position combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the equipment.

1.3 Accessibility of Controls. Controls which are not normally adjusted in flight shall not be readily accessible to flight personnel.

1.4 Effects of Tests. Unless otherwise stated, the application of the specified tests shall produce no subsequently discernible condition which would be detrimental to the continued performance of the equipment.

2.0 MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS.

The test procedures applicable to the determination of the performance of airborne low-range radio altimeter equipment under standard conditions are set forth in

Table 1—Accuracy Requirements and Measurements and Measurement Conditions

Altitude* (Ft)	Vertical Velocity (Ft/Sec)	Column 1— Pilot's Display	Column 2— Precision Equip- ment Output (Ft)
0 to 100	0 to 15	±5 Ft	±3 Ft
100 to 500	0 to 20	±5%	±5%
500 to that altitude for which the equipment is designed	0 to 20	±7%	±5%

* That "one-way" distance measured from the antenna to the terrain.

Appendix A of this standard. Test procedures which provide equivalent information may be used.

2.1 Accuracy of Pilot's Display. The altitude information displayed for the pilot's use shall not exhibit errors in excess of those set forth in Column 1 of Table 1 for 95% of all observations conducted under any combination of the measurement conditions listed with the table.

MEASUREMENT CONDITIONS

- 1—Lateral velocities from 0 to 50 feet per second
- 2—Longitudinal velocities from 0 to 300 feet per second
- 3—Pitch angle range of 0 to ±15 degrees
- 4—Roll angle range of 0 to ±20 degrees
- 5—Including all doppler shift and step errors associated with these conditions
- 6—Vertical velocity from 0 to 15 feet per second up to 100 feet and 0—20 feet per second above 100 feet.

Further, the equipment shall continue to function and provide altitude information which exhibits no errors in excess of ±20% of the indicated altitude for 95% of all observations at bank angles from 20 to 80 degrees.

2.2 Accuracy of the Precision Equipment Output. The equipment need not provide as a condition of compliance with this minimum performance standard a precision equipment output for use in conjunction with autopilots, flight directors, or similar flight control computing devices. However, the altitude data supplied by such outputs, where provided, shall not exhibit errors in excess of those set forth in Column 2 of Table 1 for 95% of all observations conducted under any combination of the measurement conditions listed in 2.1.

2.3 Precision Equipment Output Noise. The r.m.s. noise content of the data provided by the precision equipment output shall be less than 0.25 foot at all altitudes up to 100 feet.

2.4 Time Constant. When the equipment is abruptly subjected to an altitude change of not more than 10% of the indicated altitude or 20 feet whichever is smaller the transfer function time constant of the precision equipment output shall not exceed 0.1 second. Further, for transients of 20 feet or less at altitudes of 200 feet or less the system shall not lose lock. If the equipment should lose lock due to loss of signal at altitudes above 200 feet and up to the maximum altitude for which it is designed, it shall recapture the signal in less than one second.

2.5 Rate Data. The equipment need not provide a rate data output as a condition of compliance with this minimum performance standard. However, those alti-

Where:

h = altitude in feet

$/r/$ = absolute value of rate (feet/sec)

2.6 Failure Warning System. A failure warning system shall be incorporated in the equipment to indicate to the pilot and to any electronic systems which may be utilizing the altimeter data the existence of a condition of unreliability.

(a) Alarm Conditions

(1) The failure warning system shall alarm under the following condition:

(a) Loss of signal or altitude sensing information due to excessive pitch or roll.

(b) When the indicated upper limit of the equipment range is exceeded. The flag or other alarm indicating device may lag the upper limit by no more than 500 feet.

(c) Loss of power.

(d) Loss of signal or altitude sensing information due to abnormality of equipment operation or system performance.

(2) The system shall not alarm under the following conditions:

(a) When the equipment is operated under the maximum design altitude unless some abnormality of equipment operation or system performance results in a loss or inadequate signal.

(b) When self test feature is operated above the designed maximum altitude.

(b) Visual Alarm Indicator Characteristics.

(1) A flag, if used, shall be made as large as practical, commensurate with the size of the face of the indicator and/or:

(2) When in the alarm condition, the indicator pointer, if used, shall be moved off scale and masked. If a digital indicator is used, the digits shall be masked.

(3) The flag or other alarm indicating device shall be plainly visible under all normal flight deck lighting conditions.

2.7 Self Test Feature. If a self test feature is provided, it shall test the electronic integrity of the transmitter/receiver and associated instrumentation, including the failure warning system, while in flight and at any altitude at which the aircraft may be operated. It is desirable, but not mandatory, that the feature include the signal loop. The self test feature shall not cause a response in the autopilot and/or other systems utilizing altimeter data.

2.8 Transmitting Operating Frequency. The transmitter shall be operated within a frequency band available for the operation of airborne radio altimeters in the Aeronautical Radio Navigation Service and in accordance with applicable Federal Aviation Agency and

eter equipment under environmental conditions are set forth in the FAA Document for "Environmental Test Procedures for Airborne Electronic Equipment", dated August 31, 1962.

2.1 Temperature—Altitude

(a) Low Temperature—When subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedure set forth in 2.2 of Appendix A.

(3) All mechanical devices shall perform their intended functions.

(b) High Temperature—

(1) When the equipment is operated at the High Short-Time Operating Temperature:

(a) The requirements of paragraphs 2.1 and 2.2 shall not be degraded by more than a factor of 2 from the values set forth using the procedures set forth in 2.2 and 2.3 respectively, of Appendix A.

(b) The requirements of paragraph 2.6 shall be met.

(c) All mechanical devices shall operate satisfactorily.

(2) When the equipment is operated at the High Operating Temperature:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(c) Decompression (Applicable only to Category D equipment of Temperature-Altitude Test)—When the equipment is subject to this test:

(1) The requirements of paragraphs 2.1 and 2.3 shall be met using the procedures set forth in 2.2 and 2.3, respectively, of Appendix A.

(2) All mechanical devices shall perform their intended functions.

(d) Altitude—When the equipment is subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

2.2 Humidity. After subjection to this test and:

(a) Within 15 minutes from the time that primary power is applied:

(1) The requirements of paragraph 2.6 shall be met.

(2) All mechanical devices shall operate satisfactorily.

shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(b) Following the application of the Crash Safety Shocks, the equipment shall have remained in its mounting and no part of the equipment or its mounting shall have become detached and free of the shock test table or the equipment under test.¹

2.4 Vibration. When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

2.5 Temperature Variation. When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) All mechanical devices shall perform their intended functions.

2.6 Power Input Variation. When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) All mechanical devices shall perform their intended functions.

2.7 Low Voltage.

(a) When the equipment is subjected to the first part of the low voltage test procedure set forth in 9.2a. of Environmental Test Procedures for Airborne Electronic Equipment document.

(1) The equipment shall operate electrically and mechanically.

(2) The requirements of paragraph 2.6 shall be met.

(b) When the equipment is subjected to the second part of the low voltage test procedure set forth in

¹ The application of this test may result in damage to the equipment under test. Therefore, it may be conducted after the other tests are completed.

or smoke.¹

2.8 Conducted Voltage Transient.

(a) Subsequent to the subsection of the intermittent transient test, the requirements of paragraphs 2.1 and 2.3 shall be met using the procedures set forth in 2.2 of Appendix A.

(b) When being subjected to the repetitive transient test the requirements of paragraphs 2.3 and 2.6 shall be met.

2.9 Conducted Audio-Frequency Susceptibility. When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

2.10 Audio-Frequency Magnetic Field Susceptibility.

When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

2.11 Radio-Frequency Susceptibility (Radiated and Conducted). When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

2.12 Explosion (When Required). During the application of this test the equipment shall not cause detonation of the explosive mixture within the test chamber.

2.13 Emission of Radio-Frequency Energy. The levels of conducted and radiated spurious radio-frequency energy emitted by the equipment shall not exceed those levels specified in Appendix A to the Federal Aviation Agency document, "Environmental Test Procedures for Airborne Electronic Equipment", dated August 31, 1962, for the aircraft category for which the equipment is designed.

0 TEST CONDITIONS.

The following definitions of terms and conditions of test are applicable to the test procedures specified here-

1.1 Power Input Voltage-Direct Current. Unless otherwise specified, when the equipment is designed for operation from a direct current power source, all measurements shall be conducted with the power input voltage adjusted to 13.75 volts, $\pm 2\%$ for 12-14 volt equipment, or to 27.5 volts, $\pm 2\%$ for 24-28 volt equipment. The input voltage shall be measured at the receiver power input terminals.

1.2 Power Input Voltage-Alternating Current. Unless otherwise specified, when the equipment is designed for operation from an alternating current power source all tests shall be conducted with the power input voltage adjusted to design voltage $\pm 2\%$. In the case of equipment designed for operation from a power source of essentially constant frequency (e.g., 400 c.p.s.), the input frequency shall be adjusted to design frequency $\pm 2\%$. In the case of equipment designed for operation from a power source of variable frequency (e.g., 350 to 1,000 c.p.s.), tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency within the range for which the equipment is designed.

1.3 Adjustment of Equipment. The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to the application of the specified tests.

1.4 Ambient Conditions. Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure, and humidity. However, the room temperature shall be not lower than 10°C.

1.5 Warmup Period. Unless otherwise specified, all tests shall be conducted after a warmup period of not less than fifteen (15) minutes.

1.6 Description of Test Equipment.

(a) **Altitude Simulator.** The altitude simulator consists of variable and fixed RF attenuators, and coaxial cables or other suitable delays to simulate the various altitudes. The simulator must accept the altimeter energy, attenuate and delay this RF energy and present the delayed signal of the altimeter receiver. The test equipment must also include provisions to simulate the cross-coupling which exists between separate transmitter and receiver antennas. The simulator should be calibrated to provide the desired altitude of an accuracy of better than 1% and the appropriate attenuation to within ± 2.5 db. The variable attenuator shall be calibrated in radar cross-section [$\sigma_r(\theta)$]* between the values of 0.003 and 1.0.

*Defined in Appendix B

(b) Digital Voltmeter.

(c) AC VTVM.

(d) **Demodulator.** The Demodulator consists of a synchronous detector excited by an a.c. reference voltage. The bandwidth of the Demodulator should exceed 5 c.p.s. Ripple rejection should exceed 60 db. Means to set the Demodulator gain to unity should be provided. Means to balance the Demodulator output to zero should be provided.

(e) **Filter.** See Figure 2 or 3.

(f) **Alarm Signal Monitor.** The Alarm Signal Monitor consists of a simple indicator such as a pilot lamp.

(g) **Remodulator.** The Remodulator is an electronic or electromechanical switch excited by an a.c. reference voltage. It converts low frequencies to suppressed carrier modulation where the carrier frequency is the a.c. reference voltage. Means to set the Remodulator gain to unity should be provided.

2.0 TEST PROCEDURES.

The test procedures set forth herein are satisfactory for use in determining the performance of airborne low-range radio altimeters. Test procedures which provide equivalent information may be used.

2.1 Accuracy (In-Flight).

(a) **Altitude Information.** With the equipment installed in an aircraft, operate the equipment in flight over a runway or other smooth surface at altitudes and descent rates in accordance with paragraph 2.1. Determine the true altitude of the aircraft by theodolite or other means and compute the accuracy of the altitude information from the altimeter. Extrapolation of the test data by theoretical means, from the results so obtained, is permissible in order to demonstrate compliance with the standards in paragraphs 2.1 and 2.2.

(b) **Altitude Rate Information.** With the equipment installed in an aircraft, operate the equipment in flight over a runway or other smooth surface at altitudes and descent rates in accordance with paragraph 2.5. Determine the true descent rate of the aircraft and compute the accuracy of the altitude rate information from the altimeter. Extrapolation of test data by theoretical means, from the results so obtained, is permissible in order to demonstrate compliance with the standards in paragraph 2.5.

2.2 Altitude Accuracy and Loop Gain.

(a) Equipment Required:

Altitude Simulator
Digital Voltmeter
or AC VTVM
Flag Monitor

tion should remain within the limits specified. Indicator can lose track and indicate fall for $[o_o(o)]$ below 0.01.

Adjust the altitude simulator to another altitude and repeat the above measurements. Note in Appendix B a different total attenuation is required to permit the radar cross section $[o_o(o)]$ dial to remain in calibration.

2.3 Altitude Noise.

- (a) Equipment Required:
- Altitude Simulator
 - Digital Voltmeter
 - Remodulator
 - AC VTVM
 - Filter

2.4 Time Constant.

- (a) Equipment Required:
- Altitude Simulator

(b) Test Procedure. Couple the radio altimeter to the altitude simulator. Set the altitude simulator to an equivalent altitude of 100 to 200 ft. Insert a change in the delay equivalent to 10% of the indicated altitude. The analog output of the altimeter shall be observed and shall reach 63% of the ultimate change in 0.1 seconds or less with less than 5% overshoot. Consideration must be given to the time require for switching the delay in and/or out in the above measurement.

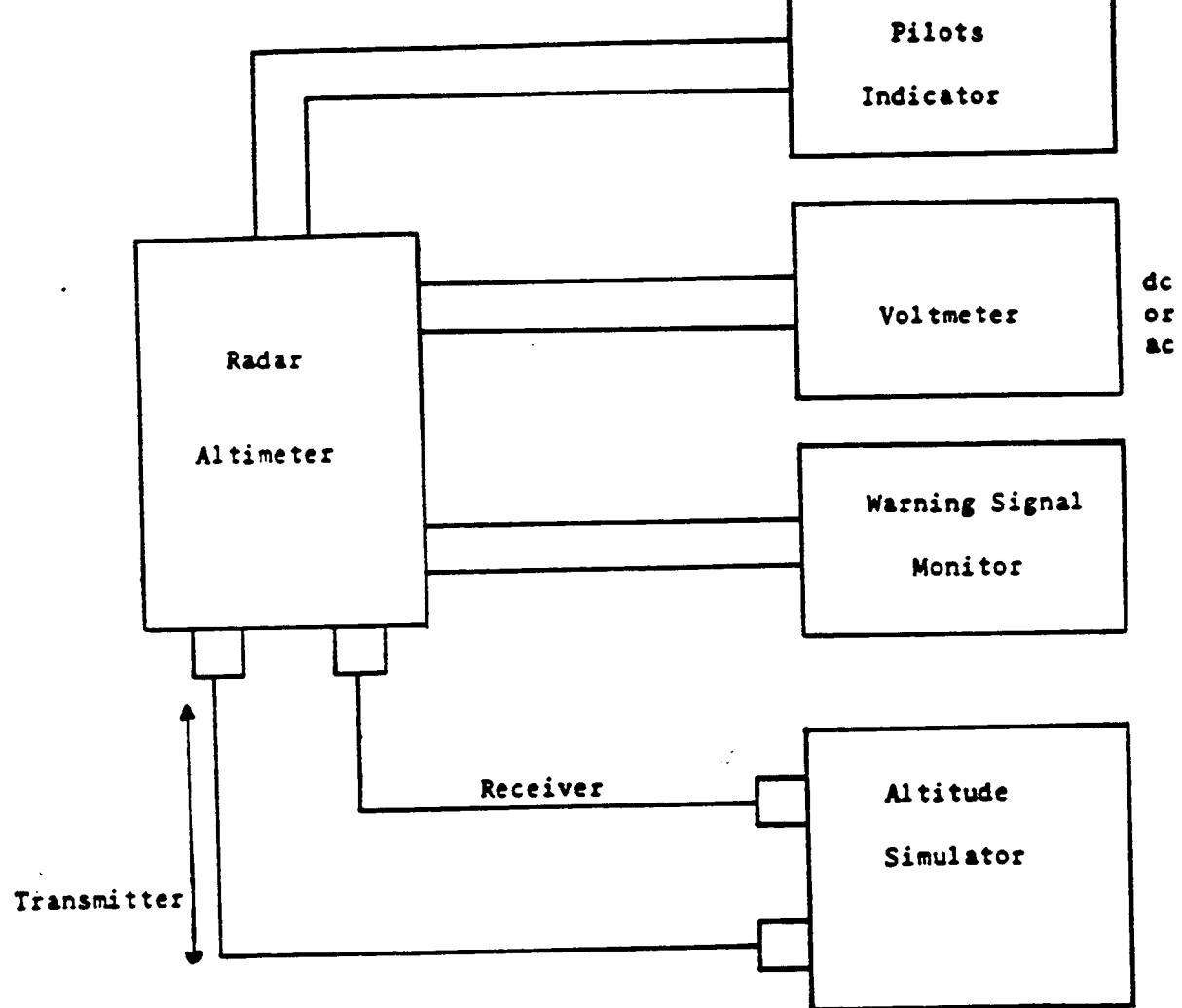


FIGURE 1

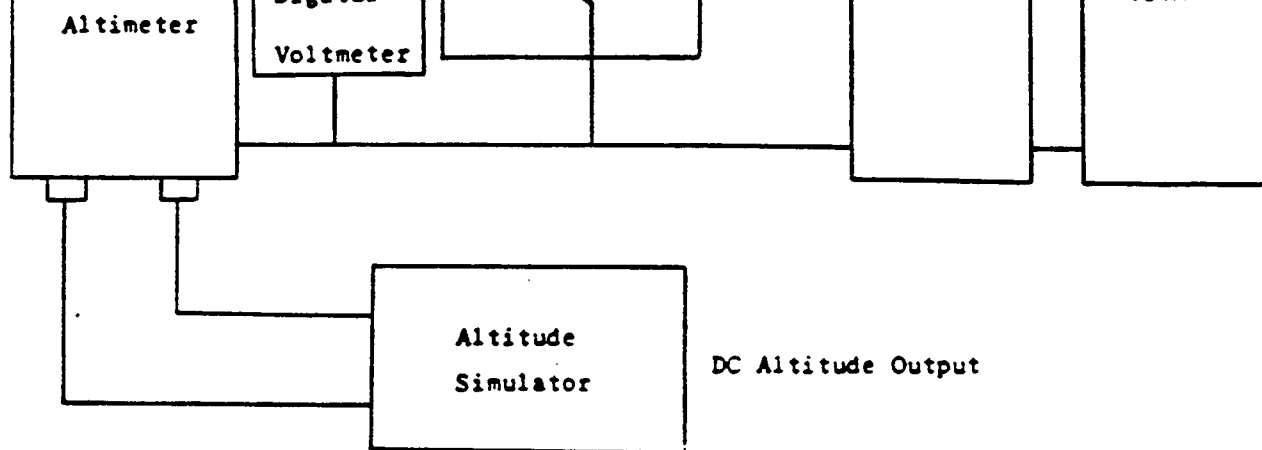


FIGURE 2

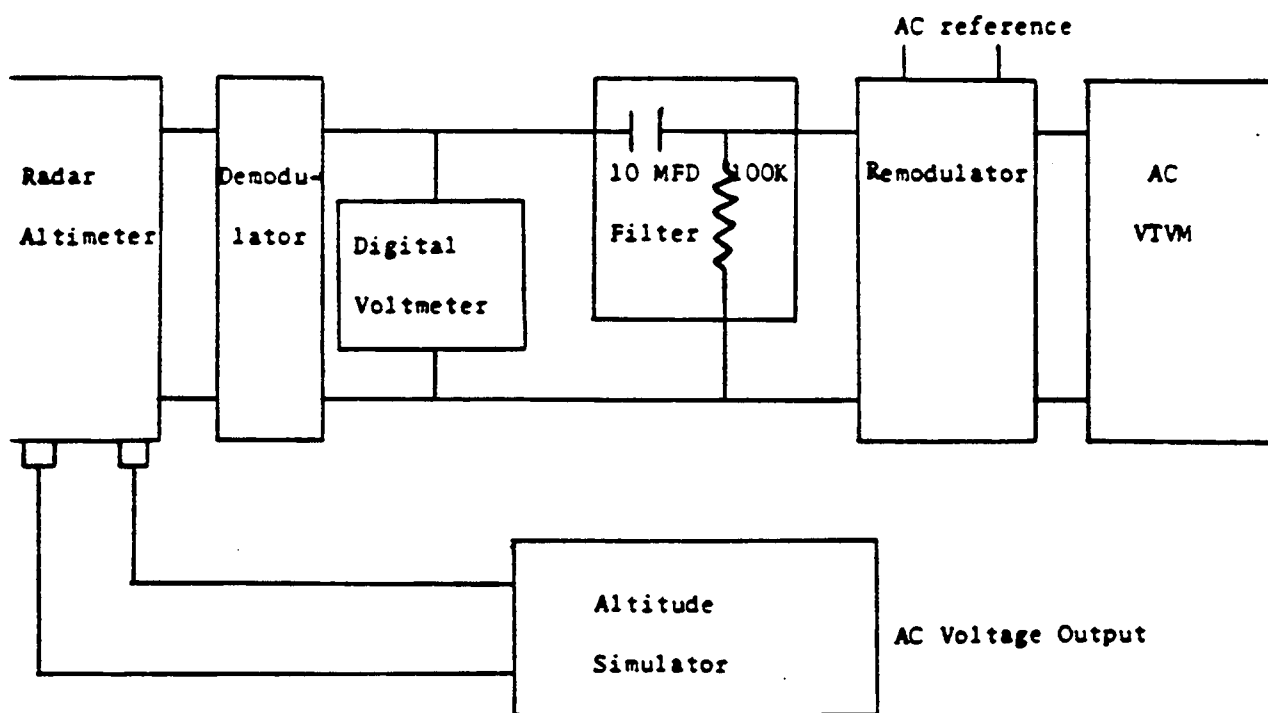


FIGURE 3

1.0 DEFINITION OF EXTERNAL LOOP LOSS

In the useful signal path, i.e., transmitting antenna to ground to receiving antenna, the External Loop Loss is defined for average power in c-w systems and peak power in pulse systems.

The external loop loss is the ratio of the available power entering the receiving antenna aperture to the power leaving the transmitter antenna aperture.

2.0 CHARACTERISTICS OF EXTERNAL LOOP LOSS

The loss defined above is independent of antenna and transmission line losses, inefficiencies, and mismatches. It deals only with the geometric power gain, (G), the beam patterns of the antennas, and the characteristics of the ground. Further, it is independent of the signal processing characteristics of the altimeter and may be measured, essentially, with an attenuator only.

3.0 EXTERNAL LOOP LOSS, BEAM LIMITED CASE

The basic formulation for external loop loss depicts a beam limited case in which it is assumed that transmitting and receiving apertures are identical. The analytical expressions for this case is:

$$L = \frac{G\lambda^2\sigma_0(O)F}{16\pi^2 H^2} = \frac{A\sigma_0(O)F}{4\pi H^2} \quad 3.1$$

where G is the power gain of either antenna (defined in terms of the actual beam pattern), λ is the wavelength, H is the altitude, $\sigma_0(O)$ is the vertical incidence unit scattering radar cross section of the ground, and F is a normalized function of H. Limitations on roll and pitch under 100 feet of altitude and the effect of finite separation of transmitting and receiving antennas is accounted for by F. A is defined as $\frac{G\lambda^2}{4\pi}$.

4.0 EXTERNAL LOOP LOSS, PULSE LIMITED CASE

In the pulsed altimeter, the external loop loss is described by Eq. (3.1) below the critical altitude, i.e., that altitude above which the performance is pulse limited.

Defining the critical altitude, H_c , as

$$H_c = \frac{c\tau}{4} \quad 4.1$$

where c is the velocity of light and τ is the pulse length. The external loop loss is defined above H_c by extending the loss.

$$\frac{G\lambda^2\sigma_0(O)F}{16\pi^2 H_c^2}$$

according to a $1/H^2$ law.

$$F(H) = M(H) V^*(H) \quad 5.1$$

5.1 M(H)

The function M(H) takes care of the fact that pitch and roll maneuvering becomes progressively limited for altitudes below 100 feet. The choice for $\sigma_0(O)$ includes margin for pitch and roll to the 3 db limits of the beamwidth for altitudes above 100 feet. It is expected that at 3 feet of altitude, however, pitch and roll will be very limited and well within the 3 db beam limits. Accordingly, it is proposed to decrease the required loop loss by 0 db at 100 feet and 6 db at 3 feet, the variation between 3 feet and 100 feet to the linear in db, i.e.,

$$10 \log M(H) = -\frac{6}{97} H + 6 \frac{16}{97} \quad 5.2$$

5.2 V*(H)

This quantity takes care of the effects of antenna spacing.

$$V^* = \frac{2(\cos^{-1} a - a \sqrt{1-a^2})}{\pi(1+a^2 \tan^2 \theta_0)^{5/2}} \quad 0 \leq a \leq 1, \quad 5.3$$

where,

$$a = \frac{D}{2H \tan \theta_0} \quad 5.4$$

D is the antenna spacing, and $2\theta_0$ is the beamwidth.

6.0 CURVES OF EXTERNAL LOOP LOSS

All that remains is to make a choice for $\sigma_0(O)$ such that the resulting external loop loss calculated is just sufficient to insure reliable operation over all terrain even for pitch and roll maneuvers out to the 3 db beamwidths. A considerable amount of data accumulated for both pulse and FM/CW altimeters in the 4200-4400 mc region involving many flight tests over a wide variety of terrain and practical problems of adjustment, maintenance and calibration of radio altimeters indicates a choice of

$$\sigma_0(O) = 6 \times 10^{-3} \quad 6.1$$

With respect to making a choice for the 1600-1660 mc range, it cannot be done on the basis of extensive flight data. Accordingly, it will be necessary to extrapolate from the 4200-4400 mc data. The trend of change of $\sigma_0(\theta)$ with frequency is slow; $\sigma_0(O)$ tending to decrease with frequency but $\sigma_0(\theta)$ tending to vary more slowly with θ as the frequency decreases. The first effect definitely increases loop loss; the second effect tends to decrease loop loss. In the absence of data to the contrary, the two effects can be assumed to cancel each other and that one may then choose the same value of $\sigma_0(O)$ for both frequency ranges. The curves which follow are based on this assumption.

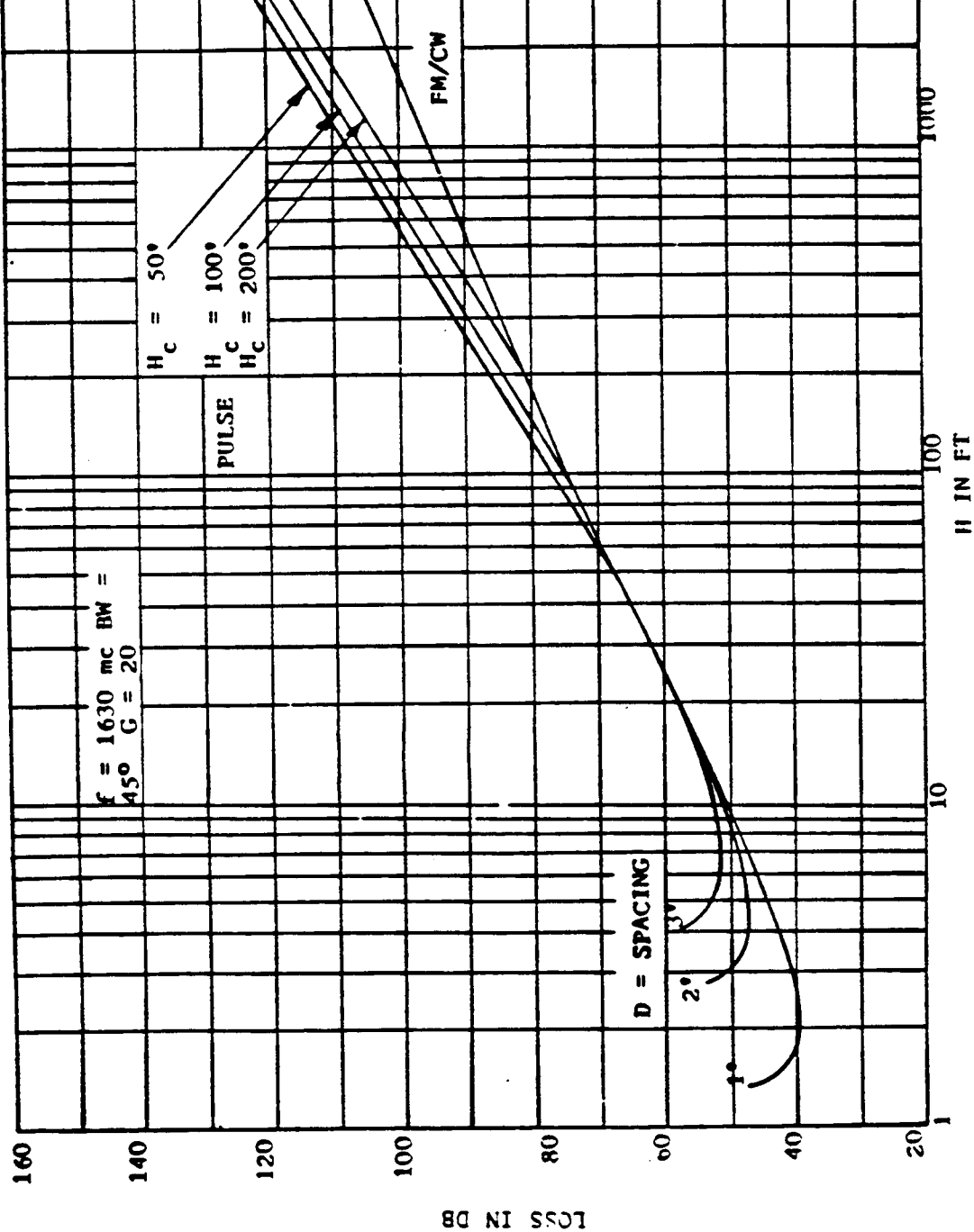


FIGURE 1—External loop loss

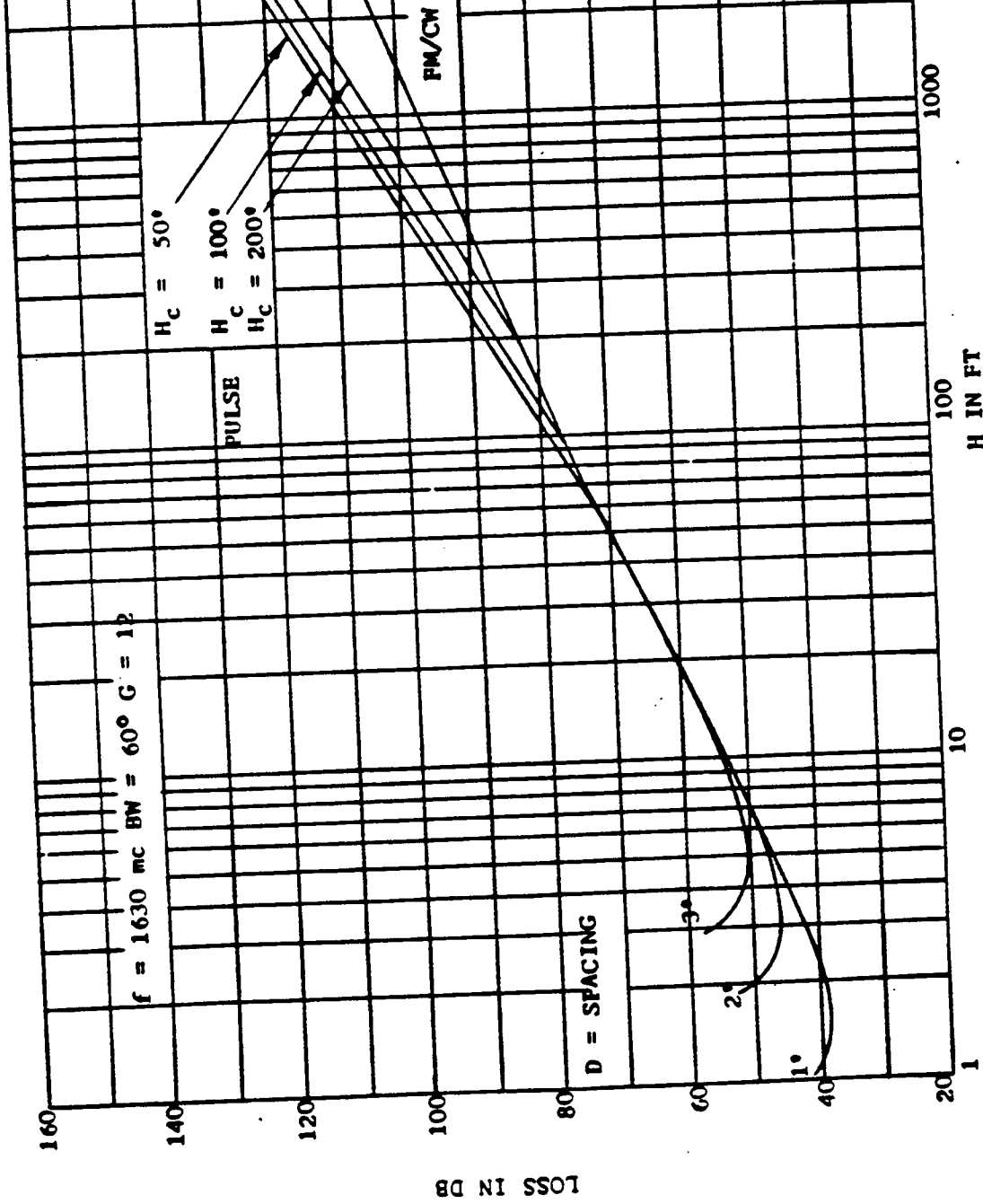


FIGURE 2.—External loop loss.

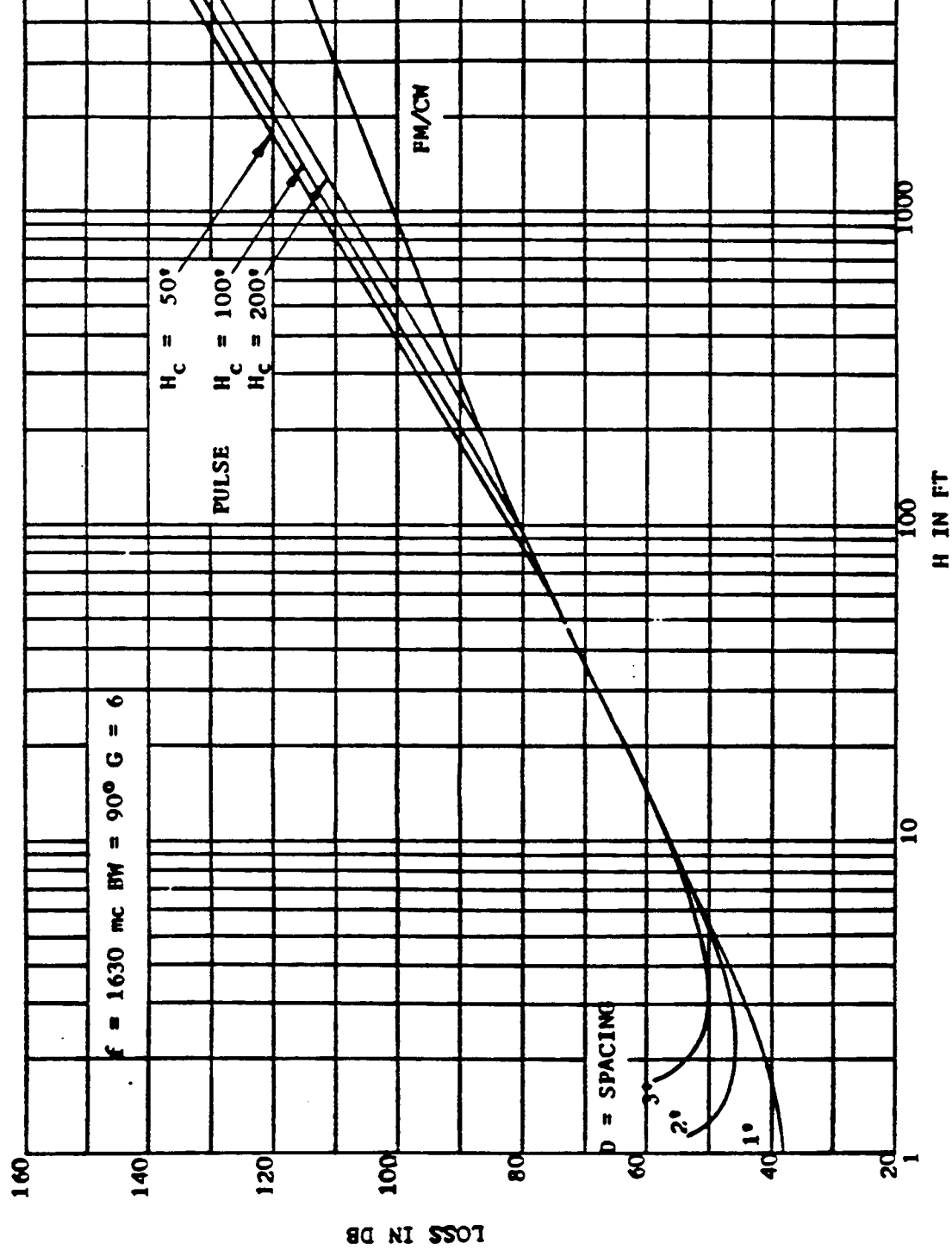


FIGURE 3.—External loop loss.

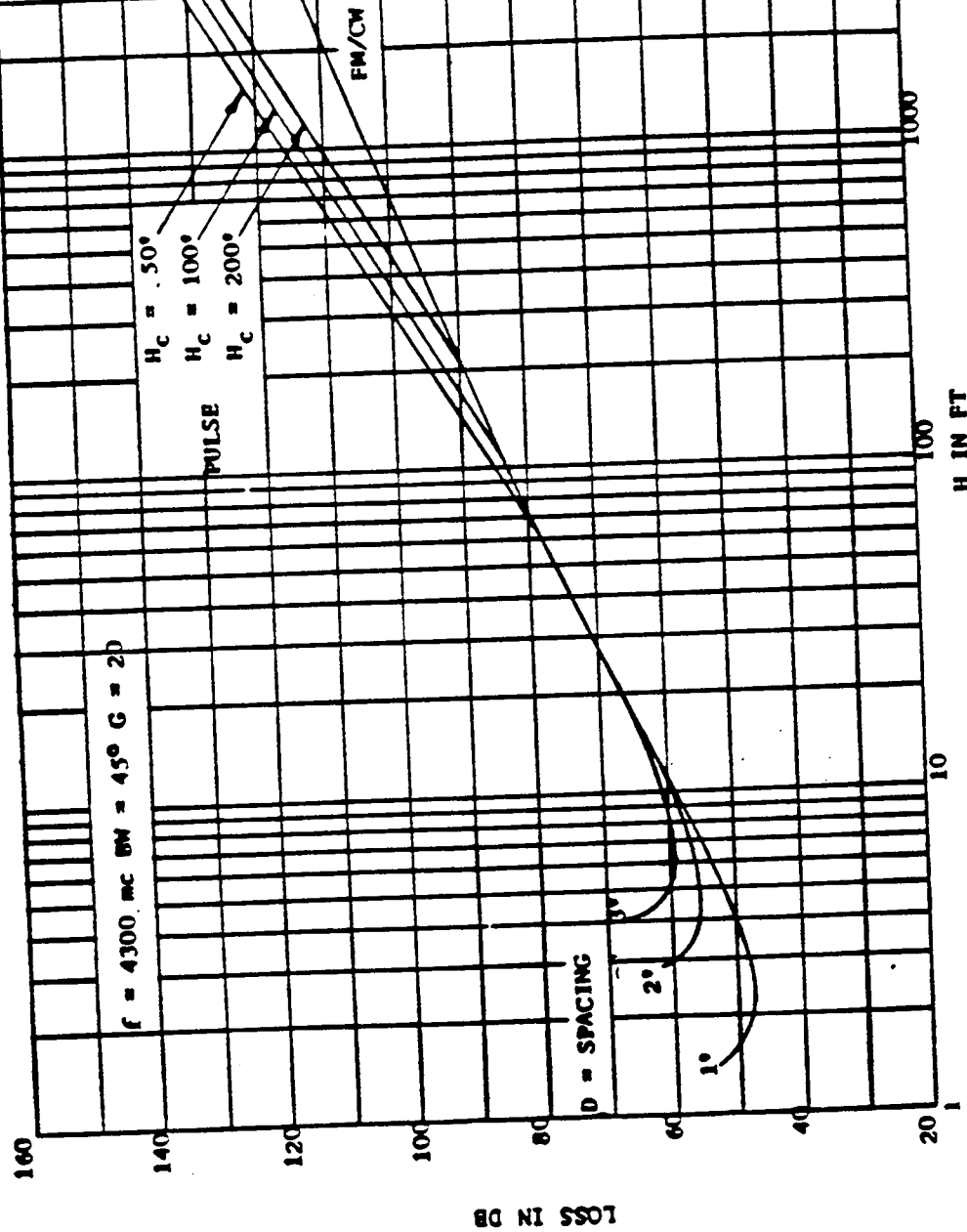


FIGURE 4.—External loop ion.

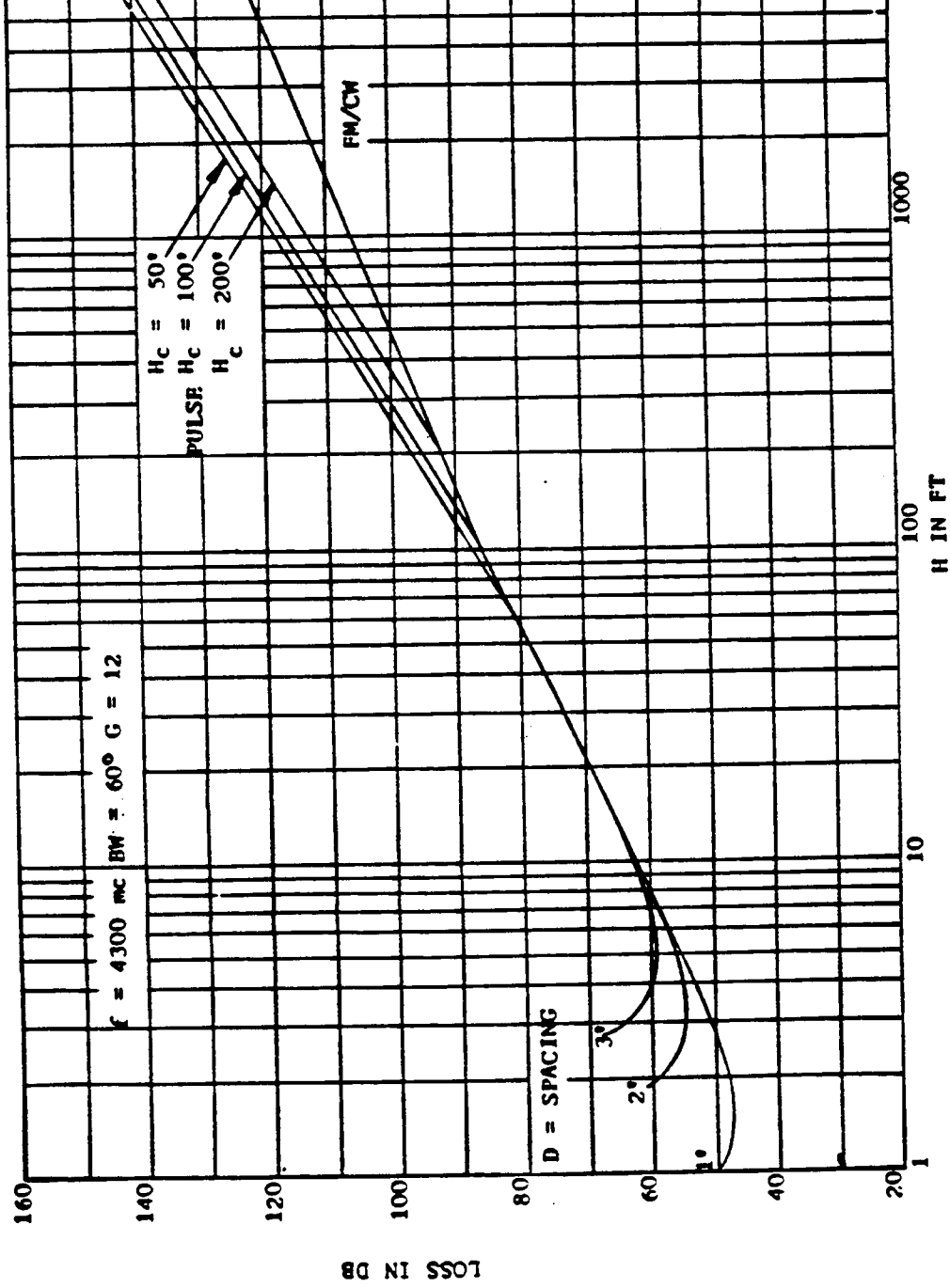


FIGURE 5.—External loop loss.

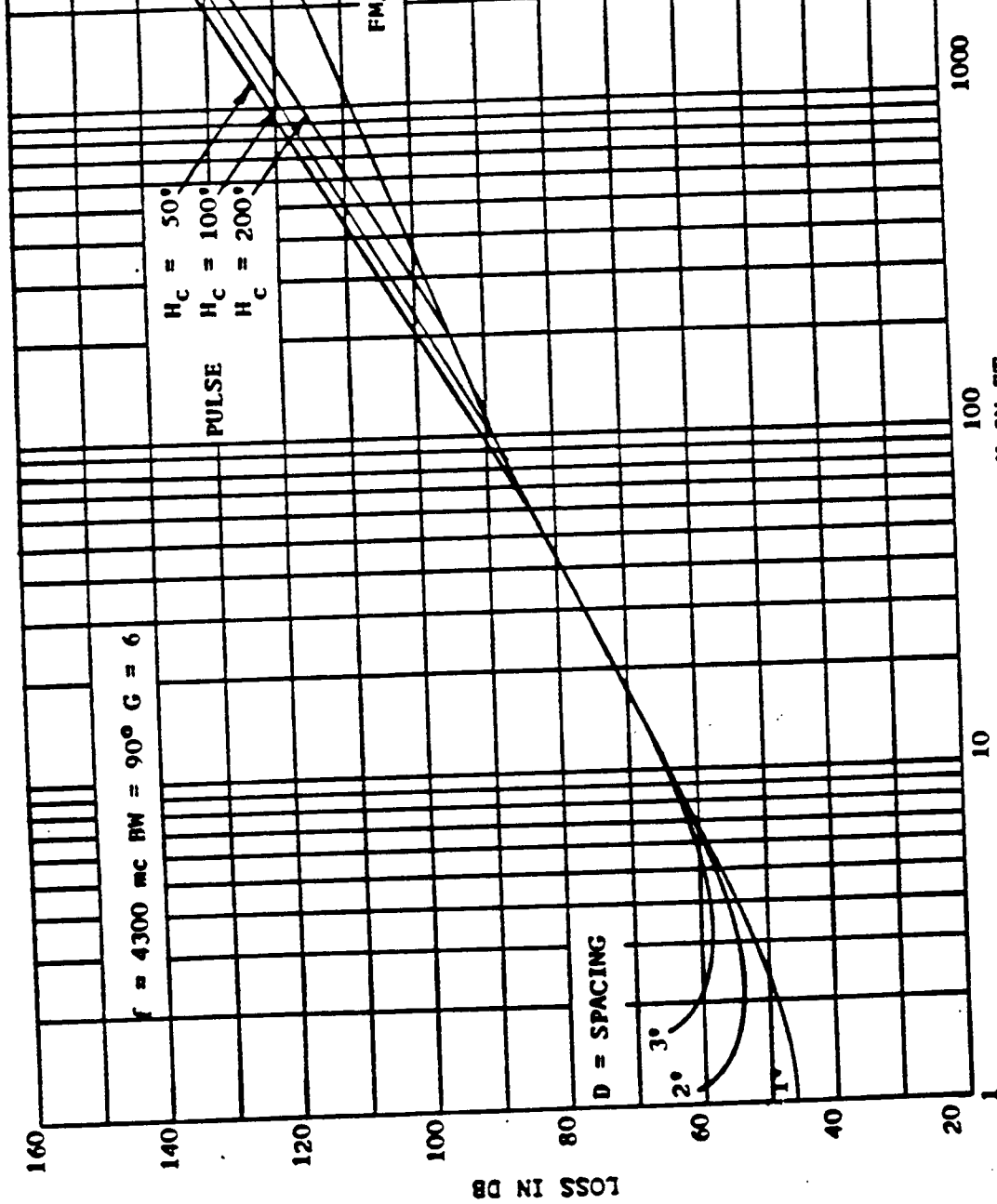


FIGURE 6.—External loop loss.

**ENVIRONMENTAL TEST PROCEDURES FOR AIRBORNE ELECTRONIC
EQUIPMENT**

AUGUST 31, 1962

2.3	Not Operating.....	1
2.4	Controlled Temperature Location.....	1
3.0	Conditions of Test.....	1
3.1	Connection of Equipment.....	1
3.2	Order of Tests.....	1
3.3	Measurement of Temperature of Air in Test Chamber.....	1
3.4	Ambient Room Temperature.....	1
3.5	Power Input Voltage.....	1
3.6	Power Input Frequency.....	1
4.0	Temperature—Altitude Test.....	1
	Category A.....	1
	Category B.....	1
	Category C.....	1
	Category D.....	1
	Category E.....	1
	Category F.....	2
4.1	Test Procedure (Low Temperature).....	2
4.2	Test Procedure (High Temperature).....	2
4.3	Test Procedure (Altitude).....	2
	Table 1.....	3
5.0	Humidity Test.....	3
6.0	Shock Test.....	3
6.1	Operational Shocks.....	3
6.2	Crash Safety Shocks.....	3
7.0	Vibration Test.....	3
7.1	Test Procedure.....	4
	Table 2.....	4
7.2	Vibration Characteristics of Categories.....	4
8.0	Temperature Variation Test.....	4
8.1	Alternate Test Procedure.....	4
9.0	Power Input Test.....	4
9.1	Power Input Variation Test.....	4
9.2	Low Voltage Test.....	5
10.0	Conducted Voltage Transient Test.....	5
10.1	Intermittent Transients.....	5
10.2	Repetitive Transients.....	6
	Figure 1.....	7
	Figure 2.....	7
	Figure 3.....	5
11.0	Conducted Audio-Frequency Susceptibility Test.....	5
11.1	D.C. Input Power Leads.....	5
11.2	A.C. Input Power Leads.....	5
12.0	Audio Frequency Magnetic Field Susceptibility Test.....	5
12.1	Categories of Equipment.....	5
12.2	Test Procedure.....	5

Figure 9.....	14
Figure 10.....	14
Figure 11.....	12
Figure 12.....	12
14.0 Explosion Test.....	12
14.1 Application and Conditions of Test.....	12
14.2 Test Procedures.....	15
Figure 13.....	

APPENDIX A

INTRODUCTION.....	Page
1.0 Standards on Emission of Spurious Radio Frequency Energy.....	17
2.0 Test Procedure.....	19
Figure 14.....	19
Figure 15.....	20
Figure 16.....	21
Figure 17.....	22
Figure 18.....	22
Figure 19.....	23
Figure 20.....	24
Figure 21.....	25
Figure 22.....	26
Figure 23.....	26
Figure 24.....	27
Figure 25.....	27
Figure 26.....	28
	28
	29

1.0 Purpose. This report sets forth Environmental Test Procedures applicable to airborne electronic equipment. The purpose of these tests is to provide a laboratory means of determining the performance characteristics of the equipment under conditions representative of those which may be encountered in actual aeronautical operations.

2.0 Definition of Terms.

2.1 Equipment Temperature Stabilization. Equipment temperature stabilization is that condition wherein (1) the temperature of the largest internal mass is within $\pm 3^\circ \text{C}$. of the specified value when the equipment is not operating, or (2) the crest temperatures of the largest internal mass do not differ by more than 5°C . when the equipment is operating.

2.2 Maximum Duty Cycle. Maximum duty cycle is the relationship between the maximum length of time for which an equipment is designed to deliver its rated output power and the length of time during which "stand-by" power only may be applied when such "ON-OFF" operation is periodic.

2.3 Not Operating. Not operating is that condition wherein no power is applied to the equipment.

2.4 Controlled Temperature Location. Controlled temperature location is a space within an aircraft in which the temperature of the air is maintained, either manually or automatically, within the limits specified in the appropriate category of Table 1 of paragraph 4.0, Temperature-Altitude Test.

3.0 Conditions of Test.

3.1 Connection of Equipment. Connect the equipment mechanically and electrically as recommended by the manufacturer, including any cooling provisions, to the extent necessary to make such tests and measurements as are required to determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

3.2 Order of Tests. The tests may be conducted in any desired order, with the exception that the humidity test shall not be conducted prior to the temperature-altitude and the vibration tests. The purpose of this exception is to determine whether materials used to protect circuit elements from moisture have lost their protective function due to deterioration from exposure to either extreme temperatures or to vibration.

3.3 Measurement of Temperature of Air in Test Chamber.

a. The temperature of the air in the test chamber shall be measured at such a location within the test chamber that the temperature of the air so measured its representative of that immediately surrounding the equipment. Measurement of chamber wall temperature is not suitable,

due to temperature lag and heat transfer from chamber wall.

b. Means of circulating the air in the test chamber may be employed to approximate a uniform air temperature condition throughout the chamber. When such means are employed, the air blast shall not be directed upon the equipment under test.

3.4 Ambient Room Temperature. When tests are conducted under "ambient room temperature", the ambient room air temperature shall be between $+10^\circ \text{C}$. and $+40^\circ \text{C}$.

3.5 Power Input Voltage. Unless specified otherwise, all tests shall be conducted with the power input voltage adjusted to design voltage $\pm 2\%$. The input voltage shall be measured at the equipment power input terminals.

3.6 Power Input Frequency.

a. In the case of equipment designed for operation from an a.c. power source of essentially constant frequency (e.g., 400 c.p.s.), the input frequency shall be adjusted to design frequency $\pm 2\%$, unless otherwise specified.

b. In the case of equipment designed for operation from an a.c. power source of variable frequency (e.g., 300 to 1,000 c.p.s.), tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the input power frequency range for which the equipment is designed, unless otherwise specified.

4.0 Temperature-Altitude Test. Several temperature-altitude test procedures are specified, according to the category for which the equipment is designed to be used, as follows:

Category A—Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 45,000 feet m.s.l.

Category B—Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 30,000 feet m.s.l.

Category C—Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 20,000 feet m.s.l.

Category D—Equipment intended for installation in controlled temperature and pressurized locations in aircraft in which the pressures are no lower than that which is equivalent to an altitude of 15,000 feet m.s.l.

Category E—Equipment intended for installation in nonpressurized but controlled temperature locations in aircraft which operate at altitudes up to 20,000 feet m.s.l.

Category F—Equipment intended for installation in nonpressurized but controlled temperature locations in aircraft which operate at altitudes up to 12,000 feet m.s.l.

¹ The temperature-altitude test and the temperature variation test may be combined, if desired. See paragraph 3.1, Alternate Test Procedure.

beric pressure, with the equipment not operating. Then operate the equipment at maximum duty cycle for a period of 15 minutes, beginning with the "ON" cycle in the case of equipment designed for intermittent duty service. Maintain the temperature of the air in the test chamber within 3° C. of the Low Operating Temperature of Table 1. Determine the compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.¹

4.2 Test Procedure (High Temperature).

a. At ambient room pressure, with the equipment not operating, stabilize the equipment temperature to within 3° C. of the appropriate High Not Operating Temperature of Table 1. After 30 minutes, adjust the test chamber air temperature to within 3° C. of the High Short-time Operating Temperature specified in Table 1. Operate the equipment at maximum duty cycle for 30 minutes. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA airborne electronic equipment Minimum Performance Standards during this 30-minute period.

¹ This is not intended to be a temperature shock test. The rate at which the temperature of the equipment under test is reduced from ambient to the appropriate Low Not Operating Temperature specified in Table 1 is optional.

² Optionally, the tests specified in this paragraph (4.1.) may be commenced with the initial temperature of the equipment at any value between the appropriate Operating and Low Not Operating Temperatures specified in Table 1.

(5) Note and determine compliance with the applicable standards of Paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

4.3 Test Procedure (Altitude).

a. Operate the equipment at maximum duty cycle. Decrease the atmospheric pressure to within 5% of the appropriate Test Altitude specified in Table 1. Conduct this test at ambient room temperature. Determine compliance with the applicable standards of Paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

b. This test is intended for application only to Category D equipment. With the equipment operating at the Test Altitude specified in Table 1, reduce the atmospheric pressure to that equivalent to the Decompression Test Altitude specified in Table 1. This reduction in pressure shall be effected within a time period not to exceed 15 seconds. Maintain this reduced pressure for at least 10 minutes, then increase the pressure to that equivalent to the Test Altitude specified in Table 1. Conduct this test at ambient room temperature. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

TABLE 1. ALTITUDE-TEMPERATURE CRITERIA

Condition		Cat. A	Cat. B	Cat. C	Cat. D	Cat. E	Cat. F
Maximum Operating Altitude		45,000'	30,000'	20,000'	15,000*	20,000'	15,000'
Test Altitude		45,000'	30,000'	20,000'	20,000*	20,000'	15,000'
Decompression Test Altitude		-----	-----	-----	40,000'	-----	-----
Not Operating Temperature	Low	-55° C.	-50° C.	-50° C.	-50° C.	-40° C.	-40° C.
	High	+71° C.	+71° C.	+71° C.	+71° C.	+71° C.	+71° C.
Short-Time Operating High Temperature		+71° C.	+71° C.	+71° C.	+80° C.	+80° C.	+45° C.
Operating Temperature	Low	-54° C.	-45° C.	-40° C.	-15° C.	-15° C.	-15° C.
	High	+35° C.	+35° C.	+35° C.	+35° C.	+40° C.	+40° C.

*The Maximum Operating Altitude and Test Altitude of Category D equipment represent atmospheres established by pressurization.

removal of the equipment from the test chamber, apply standard primary test voltage(s) to the equipment. Allow fifteen minutes following the application of primary power for the equipment to warmup. Immediately following the warmup period, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

6.0 Shock Test.

6.1 Operational Shocks.

a. Secure the equipment to a shock table by the mounting means intended for use in service installations. Apply to the shock table, with the equipment mounted in each of the following six positions, three shocks each having a peak acceleration of at least 6G and a time duration of at least 10 milliseconds.

- (1) Normal upright.
- (2) Suspended upside down.
- (3) At positions such that the longitudinal axis of the equipment successively forms angles of plus 90° and minus 90° (two positions) with the plane of the table.
- (4) At positions such that the lateral axis of the equipment successively forms angles of plus 90° and minus 90° (two positions) with the plane of the table.

b. After application of the shocks, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

6.2 Crash Safety Shocks. Apply, in each of the six equipment positions listed in paragraph 6.1, one shock having a peak acceleration of at least 15G and a time duration of at least 10 milliseconds. After application of the six shocks, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

NOTE: During this test, an equivalent weight may be substituted for the electrical and mechanical components normally mounted within or on the equipment case. Such equivalent weight shall approximate the weight of the components which it replaces and shall be so located that the center of gravity of the equipment is essentially unchanged. The equivalent weight shall not contribute to the strength of the equipment case or its mounting fastenings to a greater extent than the components it replaces.

7.0 Vibration Test.

7.1 Test Procedure.

a. So secure the equipment under test to a vibration table that sinusoidal vibratory motion is exerted parallel

to Table 2). Continue vibrating the equipment in this manner for a period of at least ninety (90) minutes.

c. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

d. Repeat the procedures specified in paragraphs 7.1 a., b., and c., with the vibratory motion applied in a direction parallel to the lateral axis of the equipment.

e. Repeat the procedures specified in paragraphs 7.1 a., b., and c., with the vibratory motion applied in a direction parallel to the vertical axis of the equipment.

f. If the equipment is to be tested under a vibration category which requires vibration tests in the 55 to 500 cycle frequency range, repeat all of the above test procedures, but starting at 55 cycles and running to 500 cycles and returning to 55 cycles with the excursion so adjusted for each frequency as to produce the constant acceleration figure specified in Table 2.^a

TABLE 2. CATEGORIZATION OF AIRCRAFT VIBRATION CHARACTERISTICS BY AIRCRAFT TYPES AND LOCATIONS THEREIN

AIRCRAFT DESCRIPTION	FUSELAGE	INSTRUMENT PANELS (VIBRATION PROTECTED OR OTHERWISE) AND ISOLATED RACKS	ANY LOCATION NOT SPECIFIED
Rotary wing aircraft	A	F	A
Turbo engine fixed wing aircraft	B	C	A
Piston engine fixed wing aircraft, heavy multi-engine type (Over 12,500 lbs.)	E	F	D
Piston engine fixed wing aircraft, light multi-engine type (Under 12,500 lbs.)	F	F	E
Piston engine fixed wing aircraft, light single engine type (Under 12,500 lbs.)	F	F	F

^a Optionally, vibratory motion may be first applied to any axis of the equipment, i.e., lateral, vertical or longitudinal. Any sequence thereafter is permissible.

^b Either a linear or logarithmic sweep (scan) may be used.

^c Optionally, the tests specified in paragraphs 7.1 a., b., c., d., e., and f., may be combined, if desired, with a total sweep time of from 2 to 6 minutes and a total time of 180 minutes.

Constant acceleration of 0.25G from 55 to 300 c.p.s.

Category D—Constant total excursion of 0.030" from 10 to 55 c.p.s. with a maximum acceleration of 5G.

Category E—Constant total excursion of 0.020" from 10 to 55 c.p.s. with a maximum acceleration of 3G.

Category F—Constant total excursion of 0.010" from 10 to 55 c.p.s. with a maximum acceleration of 1.5G.

8.0 Temperature Variation Test. Stabilize the equipment temperature at the appropriate Operating Low Temperature specified in Table 1, at ambient room atmospheric pressure with the equipment not operating. Operate the equipment at maximum duty cycle for a period of 15 minutes, beginning with "ON" cycle in the case of equipment designed for intermittent duty service, with the voltage and frequency of the primary power source adjusted to standard values. Increase the temperature of the air in the test chamber to the Operating High Temperature specified in Table 1, at a rate¹ not exceeding 1° C. per minute. In the interval between the time that the equipment temperature stabilizes at the appropriate Operating Low Temperature and the time it stabilizes at the appropriate Operating High Temperature, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards.

8.1 Alternate Test Procedure. It is permissible to combine the temperature variation test and the temperature-altitude test. In this case, proceed as follows:

(1) Conduct that portion of the temperature-altitude test specified in paragraph 4.1.

(2) Increase the temperature of the air in the test Chamber to the High Operating Temperature specified in the applicable category of Table 1 at a rate¹ not exceeding 1° C. per minute. In the interval between the time that the equipment temperature stabilizes at the appropriate Low Operating Temperature and the time it stabilizes at the appropriate High Extended-time Operation Temperature, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards.

(3) Conduct those portions of the Temperature-Altitude Test specified in paragraphs 4.2a. through 4.3b.

9.0 Power Input Test.

¹ The purpose of this test is to determine certain performance characteristics of the equipment at various temperatures between the Operating Low Temperature and the Extended-time Operation High Temperature specified in the applicable Category of Table 1.

² If desired, this rate may, if necessary, be reduced to zero to permit measurements to be taken.

³ If desired, this rate may, if necessary, be reduced to zero to permit measurements to be taken.

± 10%.

(3) In the case of equipment designed to operate from a.c. primary power sources of variable frequency, such as 300 to 1,000 c.p.s., adjust the primary power voltage to 110% of design voltage and the frequency to the highest for which the equipment is designed. The crest factor shall be 1.4, ± 10%.

NOTE: For the purposes of this test, equipment which derives a.c. power from an inverter provided exclusively for the equipment shall be considered as d.c. operated.

b. Operate the equipment at maximum duty cycle for 30 minutes, with the primary power adjusted as specified in paragraph 9.1a. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA Airborne electronic equipment Minimum Performance Standards during this 30-minute period.

c. Adjust the primary power input as follows:

(1) In the case of equipment designed to operate from a d.c. power source, adjust the primary power voltage to 90% of the design voltage.

(2) In the case of equipment designed to operate from a.c. primary power sources of essentially constant frequency, such as 400 c.p.s., adjust the primary power voltage to 90% of the design voltage and the frequency to no higher than 95% of design frequency. The crest factor shall be 1.4 ± 10%.

(3) In the case of equipment designed to operate from a.c. primary power sources of variable frequency, such as 300 to 1,000 c.p.s., adjust the primary power voltage to 90% of design voltage and the frequency to the lowest for which the equipment is designed. The crest factor shall be 1.4 ± 10%.

NOTE: For the purposes of this test, equipment which derives a.c. power from an inverter provided exclusively for the equipment shall be considered as d.c. operated.

d. Operate the equipment at maximum duty cycle for a period of 30 minutes with the primary power adjusted as specified in paragraph 9.1c. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne electronic equipment Minimum Performance Standards during this 30 minute period.

9.2 Low Voltage Test.

a. A.C. and D.C. Equipments. Operate the equipment at maximum duty cycle for a period of at least 30 minutes at an input power voltage(s) 80% of standard test voltage(s) in the case of d.c. equipment, or 87½% of standard test voltage(s) in the case of a.c. equipment. During this period, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of

Environmental Test Conditions, of the appropriate FAA Airborne Electronic Minimum Performance Standards.¹⁰

(2) With the equipment operating, reduce the input power voltage(s) from 100% to 50% of standard test voltage(s) and continue the reduction of the input power voltage(s) from the 50% level to zero input voltage(s) at a rate not greater than 2% of the standard test voltage(s) per minute. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Minimum Performance Standards.¹¹

NOTE: For the purposes of this test, equipment which derives a.c. power from an inverter provided exclusively for the equipment shall be considered as d.c. operated.

10.0 Conducted Voltage Transient Test.

10.1 *Intermittent Transients.* With the equipment operating at its normal input voltage(s), apply to each of the d.c. primary input power leads a series of positive and negative voltage transients having the characteristics (amplitude and wave form) appropriate to the applicable normal d.c. input voltages specified in Figure 1, for a period of at least ten (10) seconds and at a rate of not less than two (2) transients per second. Immediately after the ten second period, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions", of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. The positive and negative transients should be developed, applied and monitored in a manner similar to that shown in Figures 2 and 3.

10.2 *Repetitive Transients.* With the equipment operating at its normal input voltage(s), apply to each of the d.c. primary input power leads a series of positive voltage transients having the characteristics (amplitude and wave form) appropriate to the applicable normal d.c. input voltages specified in Figure 1 at a rate of not less than two (2) transients per second and, simultaneously, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. The positive voltage transients should be developed,

¹⁰ The purpose of this test is to determine those conditions resulting from decreased voltage(s) (such as relay chatter), the presence or continuation of which would contribute to malfunctioning of the equipment at standard test voltage(s).

¹¹ The purpose of this test is to determine whether the reduction of the input power voltage(s) from standard test voltage(s) to zero input voltage(s) produces evidence, external to the equipment, of smoke or fire.

When conducting this test, all equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment(s) normally associated with the equipment under test shall be adequately simulated.

11.2 *A.C. Input Power Leads.* Apply a sine wave audio frequency signal in series with each ungrounded a.c. input power lead. With the frequency of this signal successively adjusted to the second harmonic of the a.c. power frequency and to each next higher order harmonic up to 9,000 cycles, maintain the r.m.s. amplitude of this signal at not less than 5% of the nominal a.c. input voltage and determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards Under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. When conducting this test, all equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment(s) normally associated with the equipment under test shall be adequately simulated.

12.0 Audio Frequency Magnetic Field Susceptibility Test.

12.1 *Categories of Equipment.* For the purpose of this test, equipment is categorized as follows:

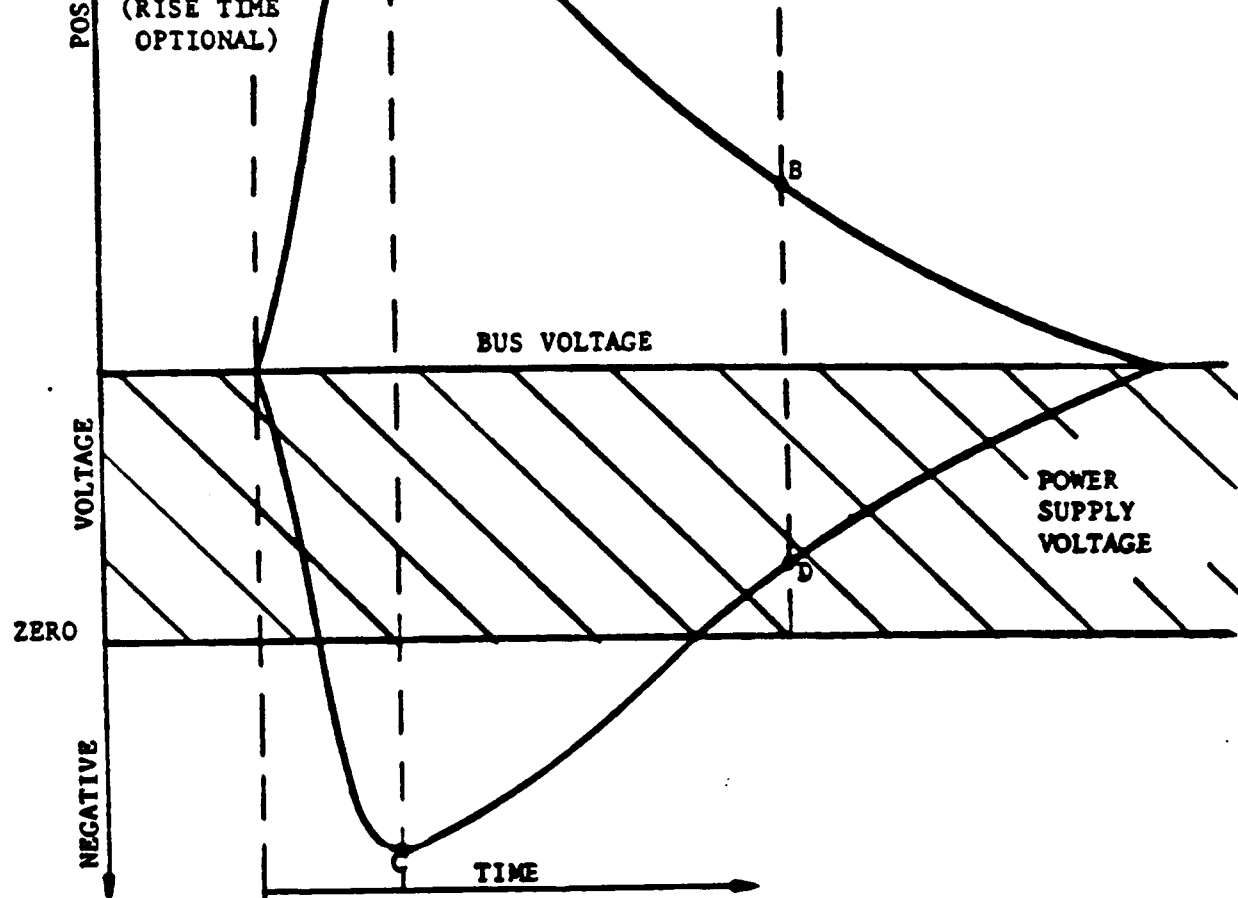
Category A—Equipment which is intended for installation in an aircraft which has an a.c. power source having a rating of 250 VA (volt-amperes) or greater.

Category B—Equipment which is intended for installation in an aircraft which has an a.c. power source having a rating of less than 250 VA, or which has no a.c. power source whatever.

12.2 Test Procedure.

Category A—Expose the equipment under test to an audio frequency magnetic field which is generated by a 400 c.p.s. current of at least 20 amperes (r.m.s.) flowing in a straight wire radiator, which is within 12 inches of the periphery of the unit of equipment under test, and deter-

¹² This test applies to equipment designed to utilize d.c. primary power which is furnished by the aircraft's electrical system. Equipment designed to operate solely on a.c. primary power need not be subjected to this test.



Normal Bus Voltage	Intermittent Transient Test Voltage		Repetitive Transient Test Voltage	
	Point A	Point B	Point A	Point B
28	+78	+46	+48	+35
14	+39	+23	+24	+17
28	Point C	Point D	X	
	-22	+10		
14	-11	+5		

FIGURE 1.—Transient voltage characteristics.

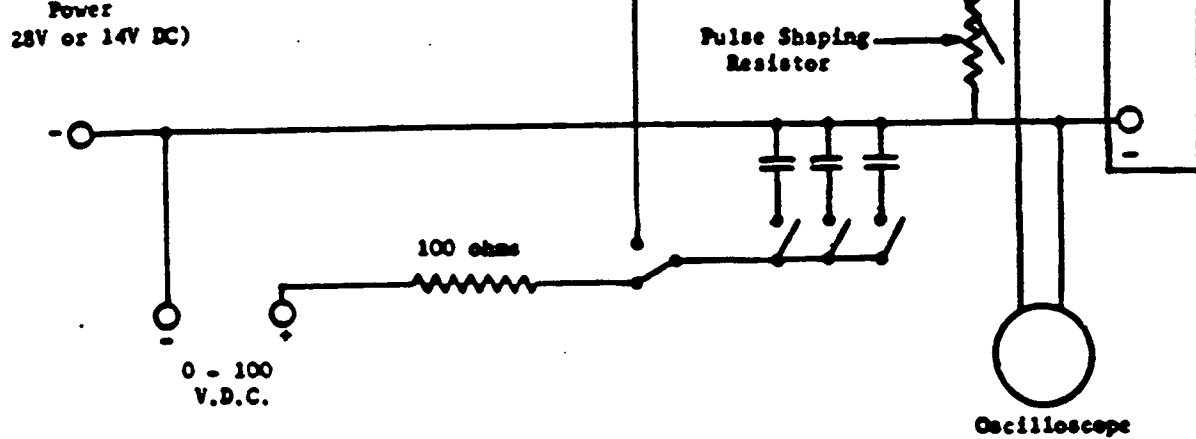


FIGURE 2.—Positive pulse generating network.

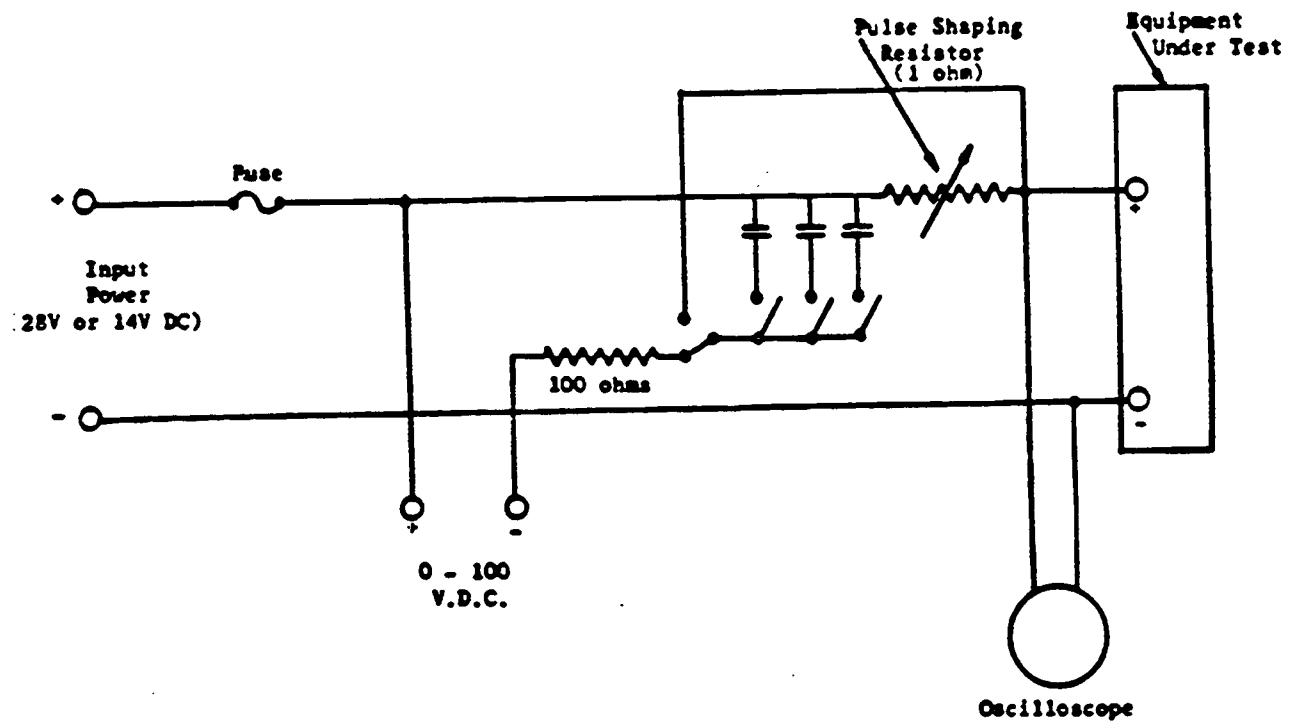


FIGURE 3.—Negative pulse generating network.

shall be routed at least two feet away from any part of the unit under test and from the radiator itself. All units of the equipment under test shall be individually tested.

Category B—No test of Category B equipment is required.

13.0 Radio Frequency Susceptibility Test (Radiated and Conducted). For the purposes of this test,¹ equipment is categorized as follows:

Category A—Equipment which is intended for installation in aircraft having a Maximum Weight of more than 12,500 pounds.

Category B—Equipment which is intended for installation in aircraft having a Maximum Weight of 12,500 pounds, or less.

13.1 General Requirements.

a. The equipment under test shall be set up on a ground plane and operated in accordance with the following criteria:

(1) **Ground Plane.**—A copper or brass ground plane, 0.01 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12-square feet or more in area with a minimum width of 30 inches, shall be used. In all cases where a shielded room is employed, the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet, and at both ends of the ground plane.

(2) **Shock and Vibration Isolators.**—The equipment under test shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are specified by the equipment manufacturer. The bonding straps furnished with the mounting base shall be connected to the ground plane. Where mounting bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

(3) **Bonding.**—Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment case and mount, together or to the ground plane. Where bonding straps are required to complete the test setup they shall have a length not greater than 5 times the width, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid. Connections made with such bond straps shall have clean metal-to-metal contact.

(4) **External Ground Terminal.**—When an external terminal is available for a ground connection on the equipment under test, this terminal shall be connected to the ground plane if the terminal is normally grounded in the installation. If the installation conditions are unknown, the terminal shall not be grounded.

¹ See "Introduction" of Appendix A for information on the relationship between the emission of spurious radio frequency energy from electrical and electronic equipment installed in an aircraft and the levels of radio frequency susceptibility signals used in this test procedure.

have electrical characteristics which closely simulate those of the normal antenna, and should be shielded. It shall contain electrical components which are used in the normal antenna (such as filters, crystal diodes, synchros, motors, etc.).

b. Test instruments shall be set up and operated in accordance with the following criteria:

(1) **Bonding.**—Interference meters used for measurement during the "conducted" test shall not be bonded to the ground plane except through the interconnecting coaxial cable. The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise.

(2) **Powerline Stabilization Network.**—One stabilization network shall be inserted in each ungrounded primary input power lead of the equipment under test. The network enclosure shall be bonded to the ground plane. The network shall be constructed in accordance with Figure 4. The input impedance characteristics of the stabilization network are shown in Figure 5.

(3) **Antenna Orientation and Positioning in Shielded Enclosures.**—The rod or dipole antenna shall be located as shown in Figures 6 or 7. The rod antenna shall be so placed that the antenna is in a vertical position. The rod antenna shall be located at the point where maximum radiation pickup is obtained when it is moved along a line parallel with the edge of the ground plane. Those measurements which use a resonate dipole antenna shall have the dipole positioned parallel with the edge of the ground plane. The dipole antenna shall be centered 12 inches ± 1 inch above the level of the ground plane. The rod or the dipole antenna shall be located at the distance from the equipment under test specified in Figures 6 and 7. When the dimensions of the dipole antenna become smaller than the test layout, the antenna shall be moved parallel to the edge of the ground plane to keep its sensitive elements adjacent to the point of maximum radiation. At frequencies from 25 up to and including 35 megacycles, the measurements shall be taken with the dipole antenna adjusted to resonance at 35 megacycles. The dipole antenna shall be adjusted to resonance at all frequencies above 35 megacycles. In screen room tests, the antennas shall be at least 1 foot away from any wall.

13.2 Conducted Radio Frequency Susceptibility Test. With the equipment under test arranged in a manner similar to that shown in Figure 8 apply through the powerline stabilization network an RF signal modulated 30% at 1,000 c.p.s. between each ungrounded primary input power lead and ground. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equip-

Test. Expose the equipment under test to a radio frequency field, the levels of which (versus frequency) are specified in Figures 11 and 12 for Category A and Category B installations, respectively. The voltages specified in Figures 11 and 12 are those existing across the radiating antenna terminals. The test signal shall be modulated 30% at 1,000 c.p.s. The type of radiating antenna to be

used shall be a rod antenna and the line stabilization networks shall be arranged in accordance with Figure 6, when using the rod antenna, and Figure 7, when using the dipole antenna. During this test, determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards.

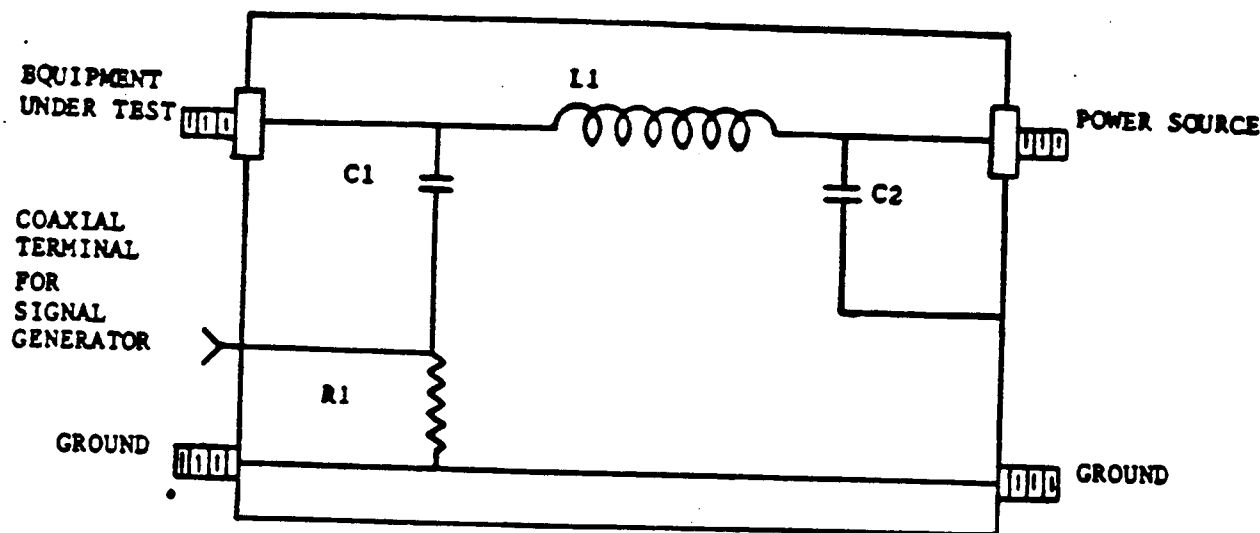


FIGURE 4.—Powerline stabilization network schematic diagram.

ENCLOSURE DATA: 14 GAGE (B & S) ALUMINUM SUGGESTED SIZE 9 $\frac{1}{2}$ IN. BY 4 BY 4 IN.
 FORM DATA: 5 $\frac{1}{4}$ IN. LENGTH, 3 IN. DIA (OD), .125 IN. WALL DRILL $\frac{1}{8}$ IN. HOLE $\frac{1}{16}$ IN. FROM EACH END.
 COIL DATA: L1=5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4 IN. WINDING LENGTH.
 WIRE DATA: AWG 6, 600 VOLT, .310 IN. DIA (OD). (FOR 50 AMPERE NETWORK.)
 CAPACITOR: C1 SHALL BE MOUNTED ON 1 IN. INSULATING BLOCK ABOVE GROUND.
 CAPACITOR DATA: C1=.1 UF, 600-VOLT DC, BATHTUB.
 C2=1 UF, 600-VOLT DC, BATHTUB, SINGLE TERMINAL CASE MOUNTED ON GROUND.
 RESISTOR DATA: R1=5,000-OHM, 5-WATT CARBON.

1. The values given for the component parts of the network are nominal. Regardless of the construction or deviation from nominal values, the network must have an impedance within 20 percent of that given in Figure 5.
2. Connecting leads to condensers and resistors should be as nearly as possible to zero length.
3. Networks may also be constructed having a 1-ohm series resistor between the line and capacitor C2. This 1-ohm resistor shall be made up from ten 10-ohm, 1-watt composition resistors.
4. The data given in this figure is suitable for the construction of 50-ampere networks. Other current-carrying networks may be constructed by changing the wire size given for the coil and the size of the over-all enclosure.
5. The 50-ohm transmission line should be extended within the enclosure right up to the location where it connects with capacitor C1.

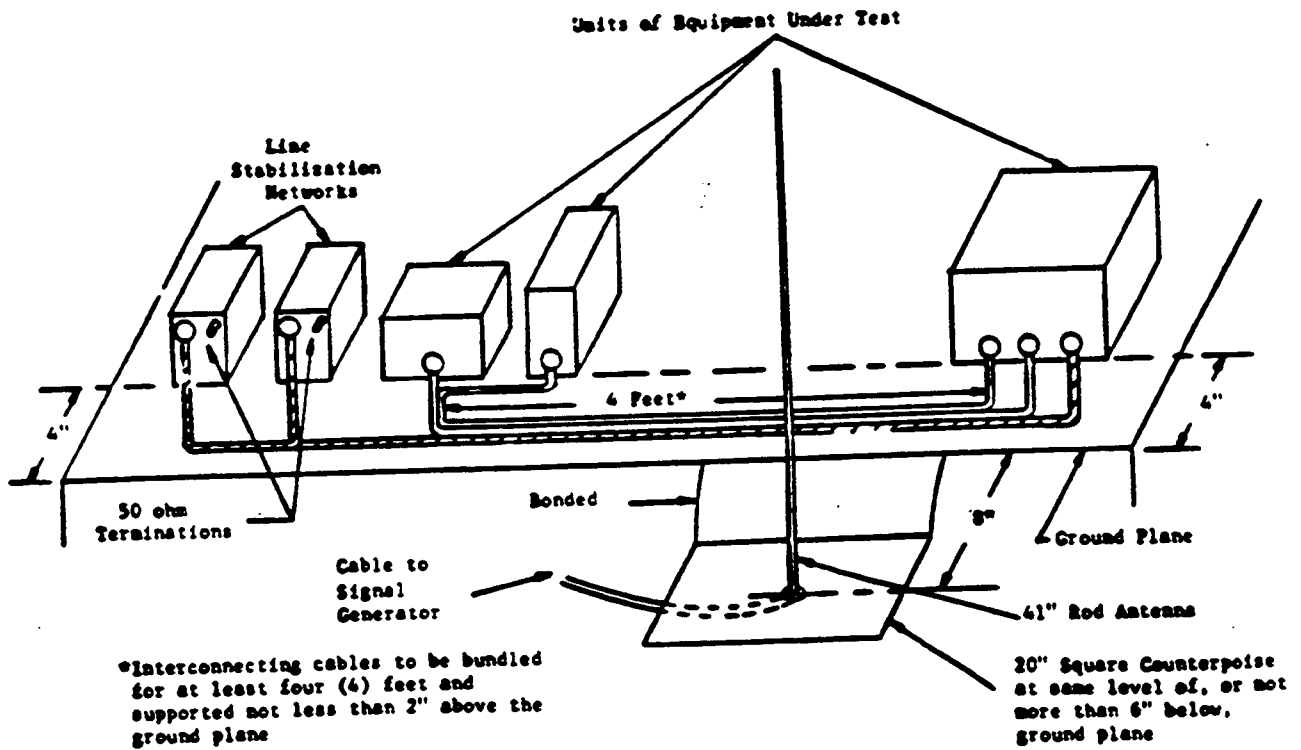
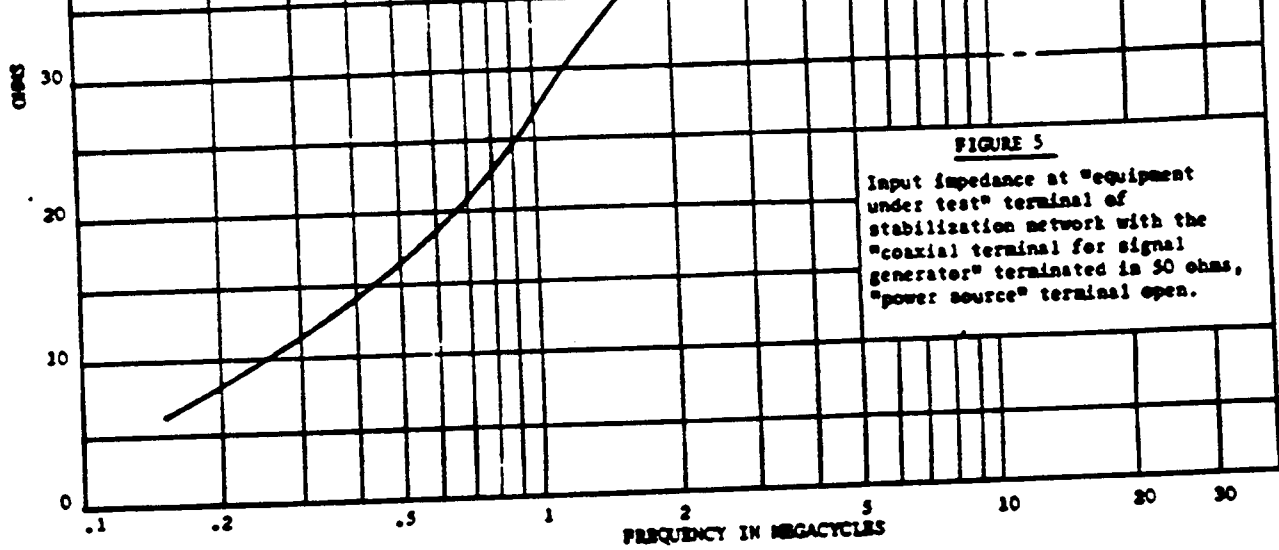


FIGURE 6.—Location of rod antenna and arrangement of equipment.

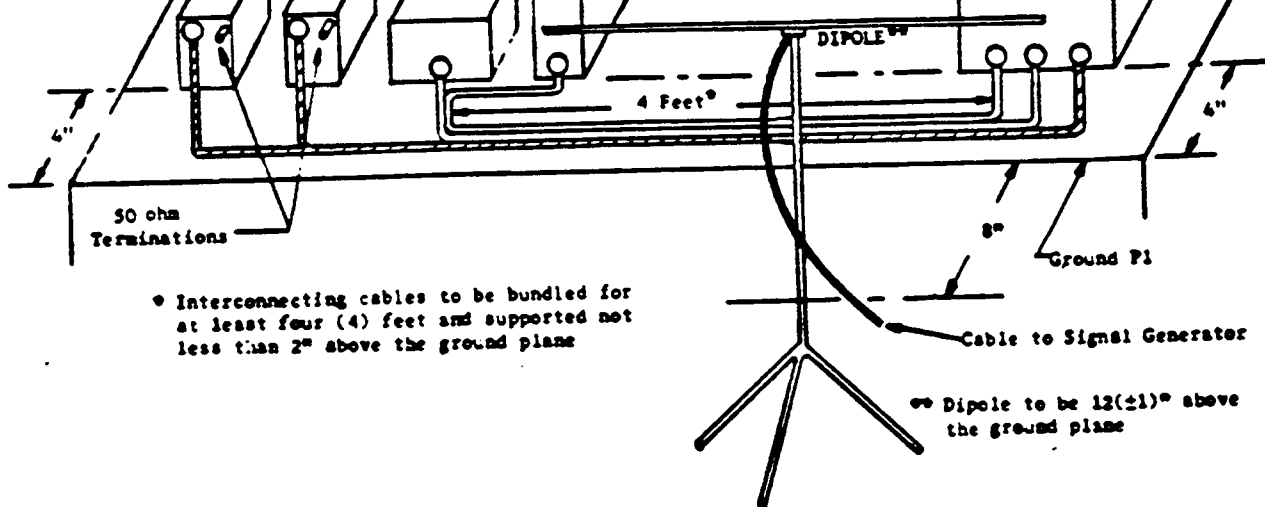


FIGURE 7.—Location of dipole antenna and arrangement of equipment.

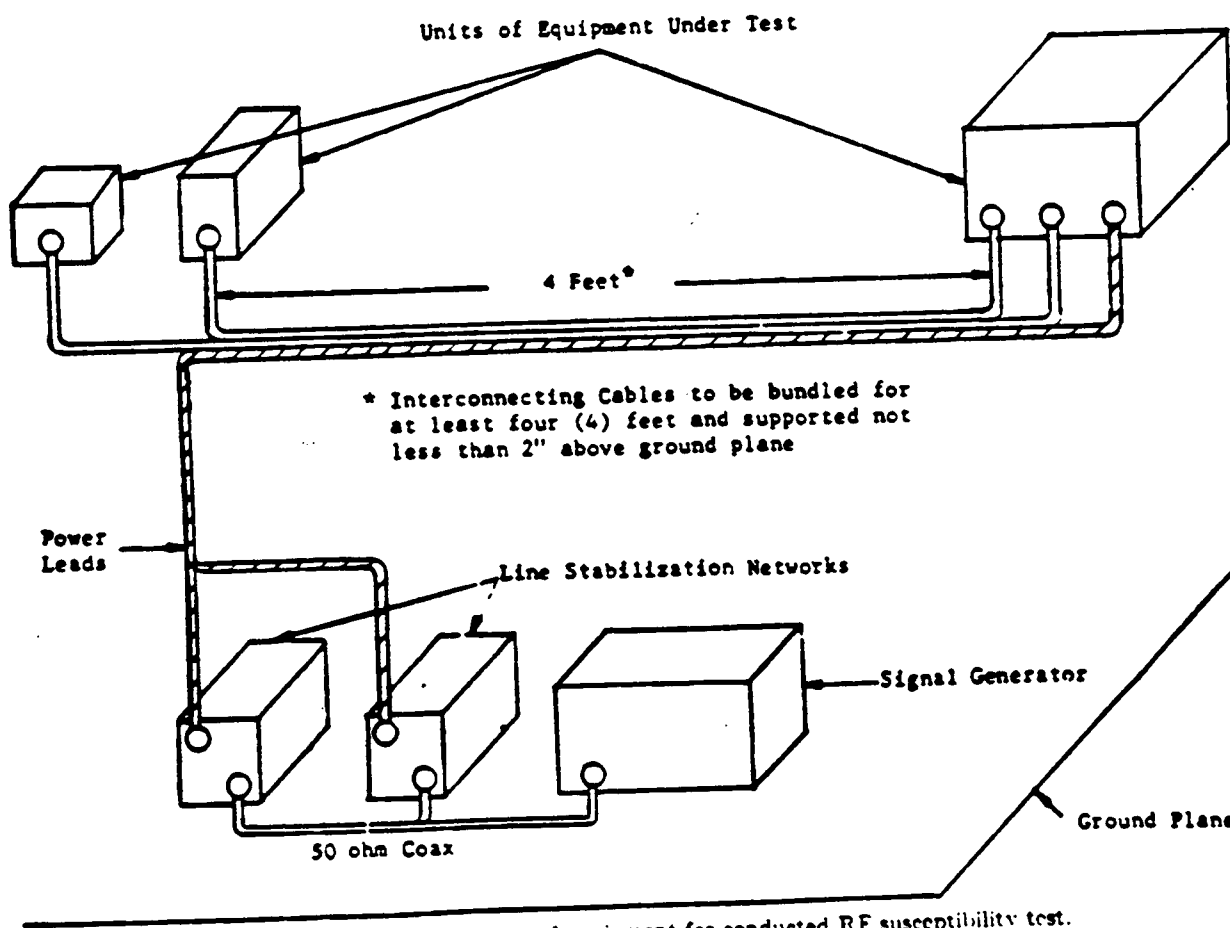
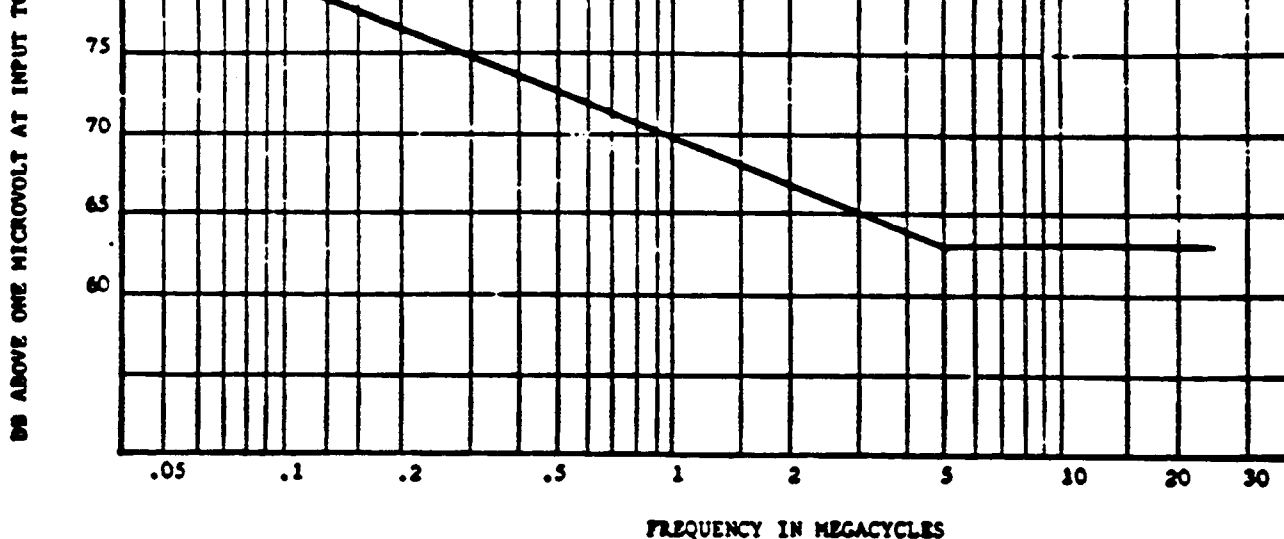


FIGURE 8.—Arrangement of equipment for conducted RF susceptibility test.



14.0 Explosion Test.

14.1 Application and Conditions of Test.

a. Application and Categories of Equipment.

(1) It is recognized that installation practices in civil aircraft and in many non-civil transport aircraft normally do not require the installation of equipment in locations where an explosive atmosphere may exist in the course of normal aircraft operations. For such installations, the Explosion Test is not applicable and the equipment is designated as Category "X" equipment.

(2) It is also recognized that, in special applications and in special purpose aircraft, equipment may be installed in locations where an explosive atmosphere may exist in the course of normal aircraft operations. For these installations, the Explosion Test is applicable and the equipment is designated as Category "E" equipment.

b. Apparatus. The test chamber shall be a type capable of providing the test environment. A suitable test chamber is described in Military Specification MIL-C-9435.

c. Fuel. The fuel used shall be 100/130 octane gasoline.

d. Failure Criteria. If the equipment causes explosion at any of the test altitudes, it shall be considered to have failed to pass the test and no further trials need be attempted.

e. Applicability Exceptions. Sealed equipment, connecting wires, and cables shall be considered explosion-proof and require no test.

f. General Conditions.

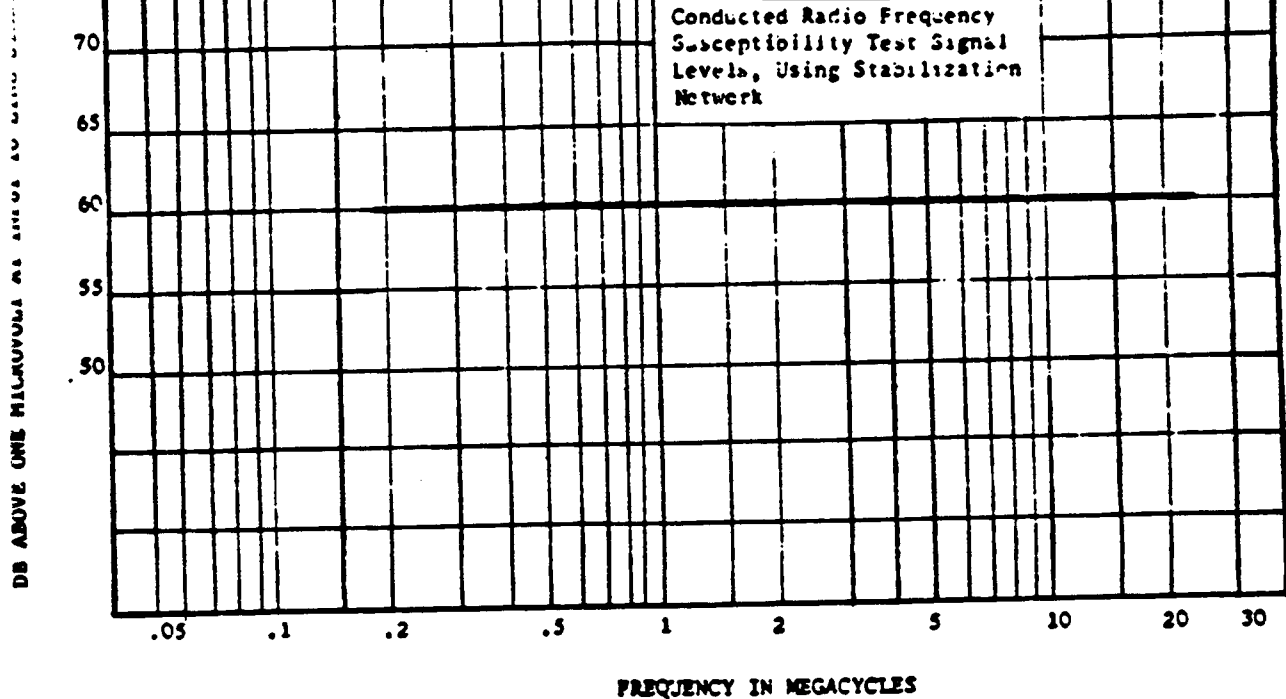
(1) When necessary, large items of electrical equipment, such as motors, large relays, etc., shall be prepared for explosion-proof testing by drilling and tapping openings in the case for inlet and outlet connections to the fuel vapor air mixture circulating system and for mounting a spark plug. The spark plug is used only for igniting the vapor air mixture in the equipment to insure the presence of an explosive mixture inside the equipment on test. Small items of equipment such as switches, circuit breakers, etc., shall not be drilled and tapped for mounting a spark plug when it is not practicable.

(2) When the explosion-proof test of paragraph 14.2a.(2) is being performed, dust or other auxiliary covers not intended to be explosion-proof may be removed or loosened to facilitate penetration of the explosive mixture.

14.2 Test Procedures.

a. Procedure I. This procedure is designed to determine the explosion producing characteristics of equipment not provided with cases designed to prevent flame or explosion propagation.¹⁴

¹⁴ See additional test procedure under paragraph 14.2b.



(1) Preparation for Test.

(a) The equipment shall be installed in the test chamber in such a manner that normal electrical operation is possible and that mechanical controls may be operated through the pressure seals from the exterior of the chamber. All external covers of the equipment shall be removed or opened to insure adequate circulation of the explosive mixture. Large equipment, comprising multiple units, may be tested one or more units at a time by extending electrical connections through the cable port to units located externally.

(b) The equipment shall be operated to determine that it is functioning properly and to observe the location of any sparking or high temperature components which may constitute potential explosion hazards.

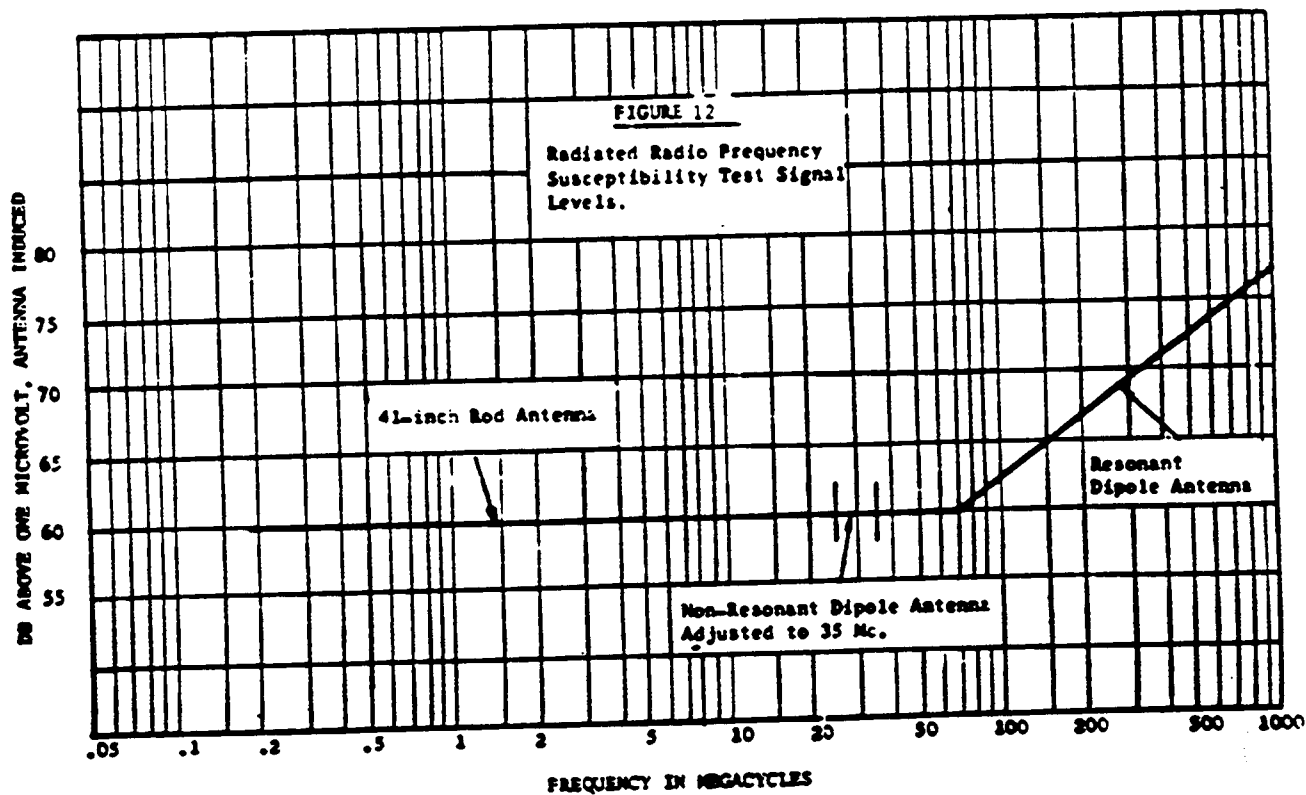
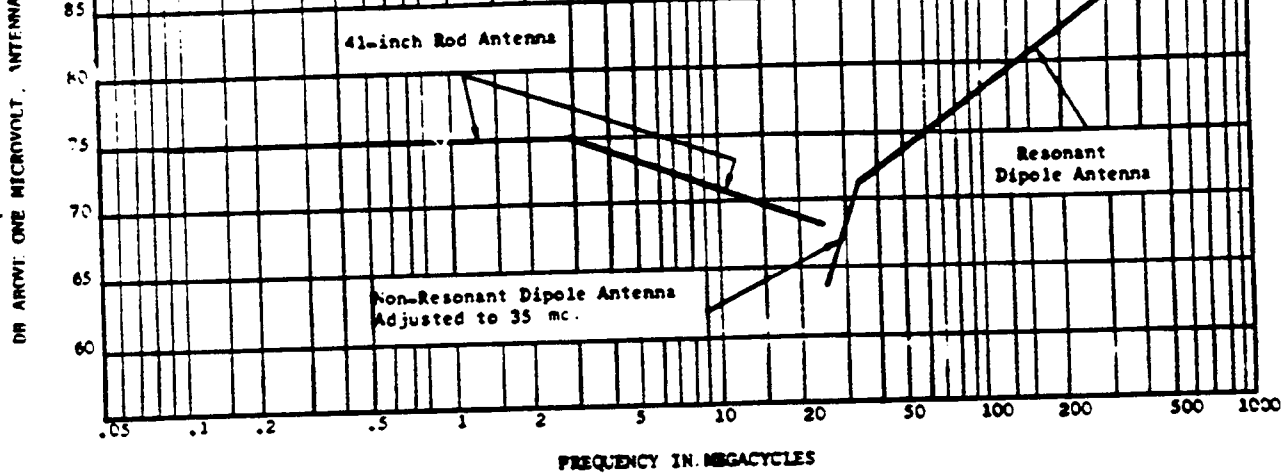
(c) Mechanical loads on drive assemblies and servomechanical and electrical loads on switches and relays may be simulated when necessary, if proper precaution is given to duplicating the normal load in respect to torque, voltage, current, inductive reactance, etc. In all instances, it is preferable to operate the equipment as it normally functions in the system during service use.

(2) Test Procedure. The test shall be conducted at test altitudes of ground level to 5,000 feet, 20,000 feet, and 40,000 feet, except that the highest test altitude shall not exceed the design requirement of the equipment.

(a) The test chamber shall be sealed and the ambient temperature within shall be raised to $+71 \pm 3^\circ \text{C}$, or to the maximum temperature for which the equipment is designed to operate (if lower than 71°C). The temperature of the test item and the chamber walls shall be permitted to rise to within 11°C of that of the chamber ambient air, prior to introduction of the explosive mixture.

(b) The internal test chamber pressure shall be reduced sufficiently to simulate an altitude approximately 10,000 feet above the desired test altitude. The quantity of fuel, as determined from Figure 13 shall be introduced into the chamber. A time of 3 ± 1 minutes shall be allowed for the introduction and vaporization of the fuel. Air shall be admitted into the chamber until a simulated altitude of 5,000 feet above the test altitude is attained.

(c) Operation of the equipment shall then be commenced, all making and breaking electrical contacts being actuated. If high temperature components are present, a warmup time of 15 minutes shall be permitted. If no explosion results, air shall be admitted into the chamber so as to steadily reduce the altitude below the desired test altitude to an elevation 5,000 feet below that altitude. The operation of the equipment shall be continuous throughout this period of altitude reduction and all making and breaking electrical contacts shall be operated as frequently as possible.



propagation of internal case explosions.

(1) Preparation for Test.

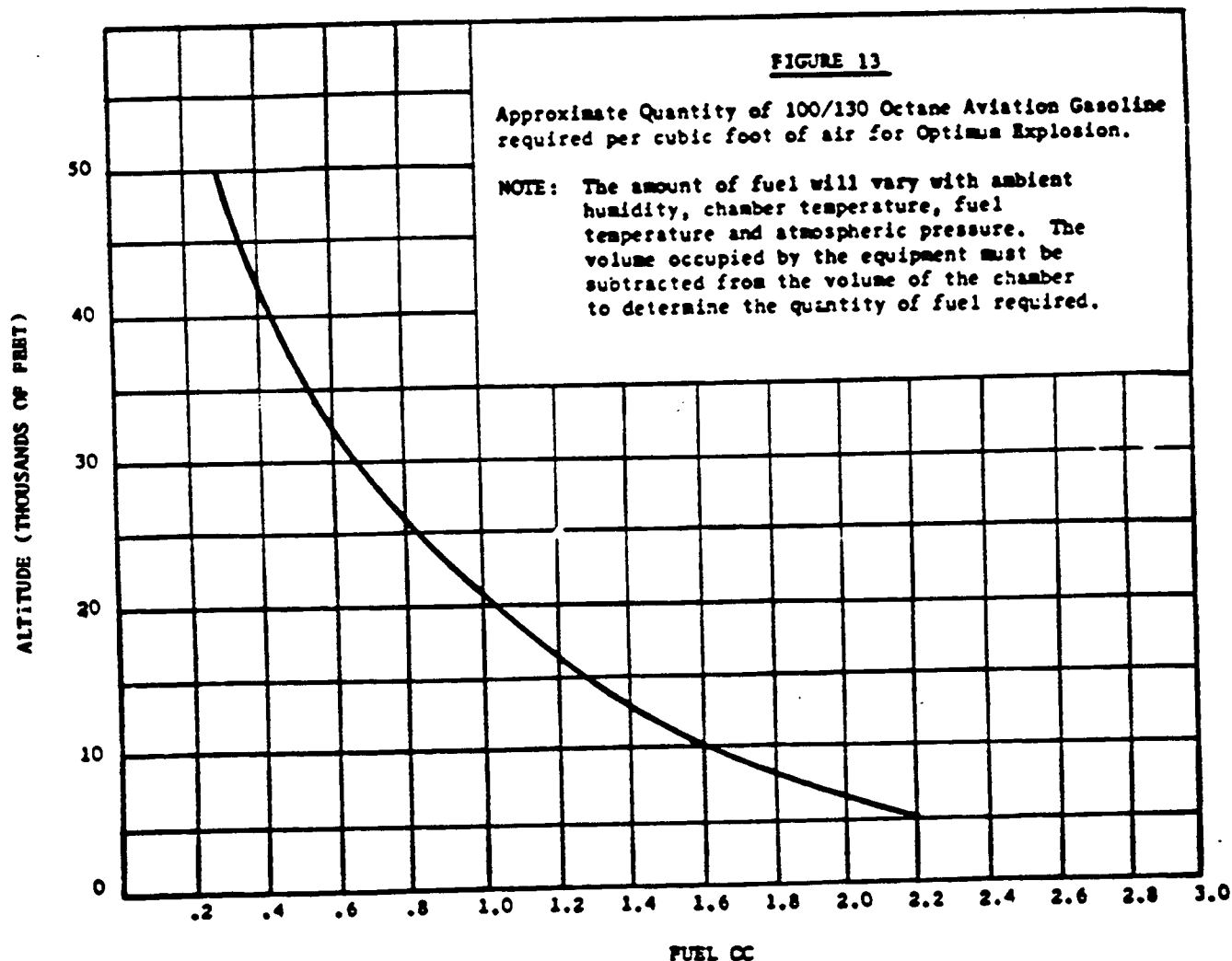
(a) The case, with the equipment in position within, shall be installed in the explosion chamber. Testing shall be accomplished without consideration of the equipment operating characteristics; accordingly, the equipment need not be operated. Adequate circulation of the explosive mixture throughout the case shall be provided by optional means.

(b) If it is necessary to drill the case for insertion of a hose from a blower, adequate precaution shall be

¹¹See additional test procedure under paragraph 14.2a.

(a) The chamber shall be sealed and the internal pressure reduced sufficiently to simulate an altitude between local ground level and 5,000 feet. The ambient chamber temperature shall be at least 25° C. An explosive mixture shall be obtained within the test chamber. (See paragraph 14.2a.(2)(b).

(b) The internal case ignition source shall be energized, in order to cause an explosion within the case. The occurrence of an explosion within the case may be detected by use of a thermocouple inserted in the case and connected to a sensitive galvanometer outside the test



the connection of the equipment to the power source frequency energy that any one electrical or electronic equipment in that aircraft will emit. It is concluded, therefore, that if the foregoing RF Conducted and Radiated Susceptibility Tests are to achieve their intended purposes, a compatible standard on the maximum permissible level

Accordingly, one of the following standards (and associated test procedure), as appropriate for the maximum weight of the aircraft in which the electrical/electronic equipment is intended to be installed must be applied to each unit of equipment incorporated in such installation

not appear on any power line normally connected to an aircraft bus or other equipment.

c. Radiated RF Interference. Radiated interference fields generated by the equipment within the frequency ranges and in excess of the values shown in Figures 20, 21, 22, and 23 for Categories A and B, respectively, shall not be radiated from any unit, cable (including, but not limited to, control, pulse, i-f, video, antenna transmission and power cables) or interconnecting wiring. This requirement includes, but is not limited to, oscillator radiation, other spurious emanations and broadband interference. This does not include radiation emanating from antennas or, in the case of transmitters, any radiation on the selected frequency $\pm 50\%$ of the band of frequencies between adjacent channels.

NOTE: The emission of spurious radio-frequency energy from the equipment resulting from manual operation of switches, but not including any electrical or electromechanical operations resulting from manual operation of switches, may exceed the limits stated in paragraphs 1.0b. and 1.0c. if its duration does not exceed one second.

2.0 Test Procedure.

a. Equipment Required.

(1) Interference measuring instrument.—Empire Devices Model NF-105 (including heads and antennas), or equivalent.

(2) Line stabilization networks that meet the requirements of paragraph 2.b.(2)(b).

b. General Requirements.

(1) The equipment under test shall be set up on a ground plane and operated in accordance with the following criteria:

(a) Ground Plane.—A copper or brass ground plane, 0.01 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12-square feet or more in area with a minimum width of 30 inches, shall be used. In all cases where a shielded room is employed, the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet and at both ends of the ground plane.

(b) Shock and Vibration Isolators.—The equipment under test shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are specified by the manufacturer. The bonding straps furnished with the mounting base shall be connected to the ground plane. Where mounting bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

(c) Bonding.—Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment

(e) Interconnecting Cables.—All equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipments associated with the equipment under test shall be adequately simulated.

(f) Dummy Antennas.—The dummy antenna shall have electrical characteristics which closely simulate those of the normal antenna, and should be shielded. It shall contain electrical components which are used in the normal antenna (such as filters, crystal diodes, synchros, motors, etc.).

(2) Test instruments shall be set up and operated in accordance with the following criteria:

(a) Bonding.—Interference meters used for measurement during the "conducted" test shall not be bonded to the ground plane except through the interconnecting coaxial cable. The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise.

(b) Powerline Stabilization Network.—One stabilization network shall be inserted in each ungrounded primary input power lead of the equipment under test. The network enclosure shall be bonded to the ground plane. The network shall be made in accordance with Figure 14. The input impedance characteristics of the stabilization network are shown in Figure 15.

(c) Antenna Orientation and Positioning in Shielded Enclosures.—The rod or dipole antenna shall be located as shown in Figures 25 or 26. The rod antenna shall be so placed that the antenna is in a vertical position. The rod antenna shall be located at the point where maximum radiation pickup is obtained when it is moved along a line parallel with the edge of the ground plane. Those measurements which use a resonant dipole antenna shall have the dipole positioned parallel with the edge of the ground plane. The antenna shall be centered 12 inches ± 1 inch above the level of the ground plane. The rod or the dipole antenna shall be located at the distance from the equipment under test specified in Figures 25 or 26. When the dimensions of the dipole antenna become smaller than the test layout, the antenna shall be moved parallel to the edge of the ground plane to keep its sensitive elements adjacent to the point of maximum radiation. At frequencies from 25 up to and including 35 megacycles, the measurements shall be taken with the dipole antenna

quired.
EQUIPMENT
UNDER TEST

COAXIAL
TERMINAL
FOR
MEASURING
SET

GROUND

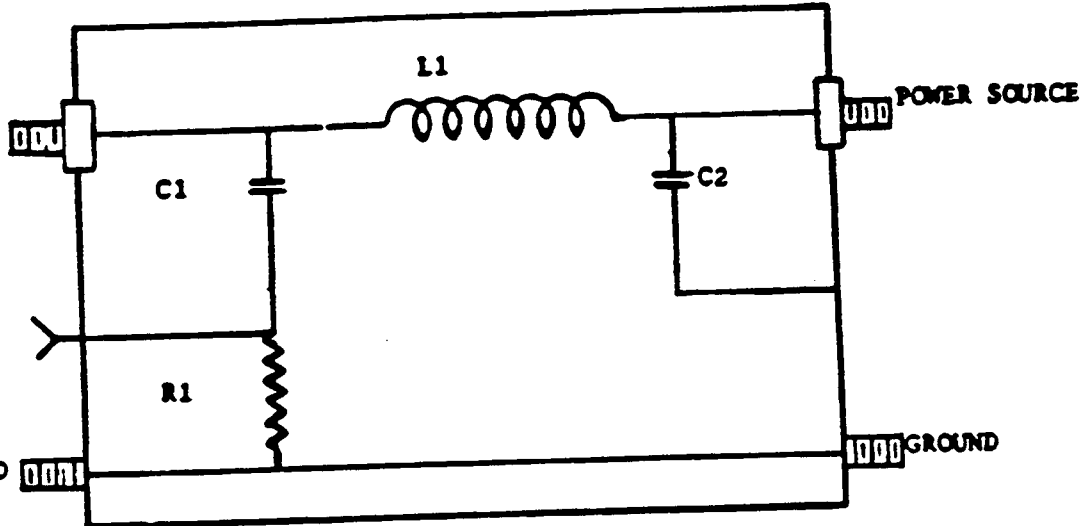


FIGURE 14.—Powerline stabilization network schematic diagram.

ENCLOSURE DATA: 14 GAGE (B & S) ALUMINUM SUGGESTED SIZE 9 $\frac{1}{2}$ IN. BY 4 BY 4 IN.
FORM DATA: 5 $\frac{1}{2}$ IN. LENGTH, 3 IN. DIA (OD), .125 IN. WALL DRILL $\frac{1}{8}$ IN. HOLE $\frac{1}{16}$ IN. FROM EACH END.

COIL DATA: L1=5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4 IN. WINDING LENGTH.

WIRE DATA: AWG 6, 600 VOLT, .310 IN. DIA (OD). (FOR 50-AMPERE NETWORK.)

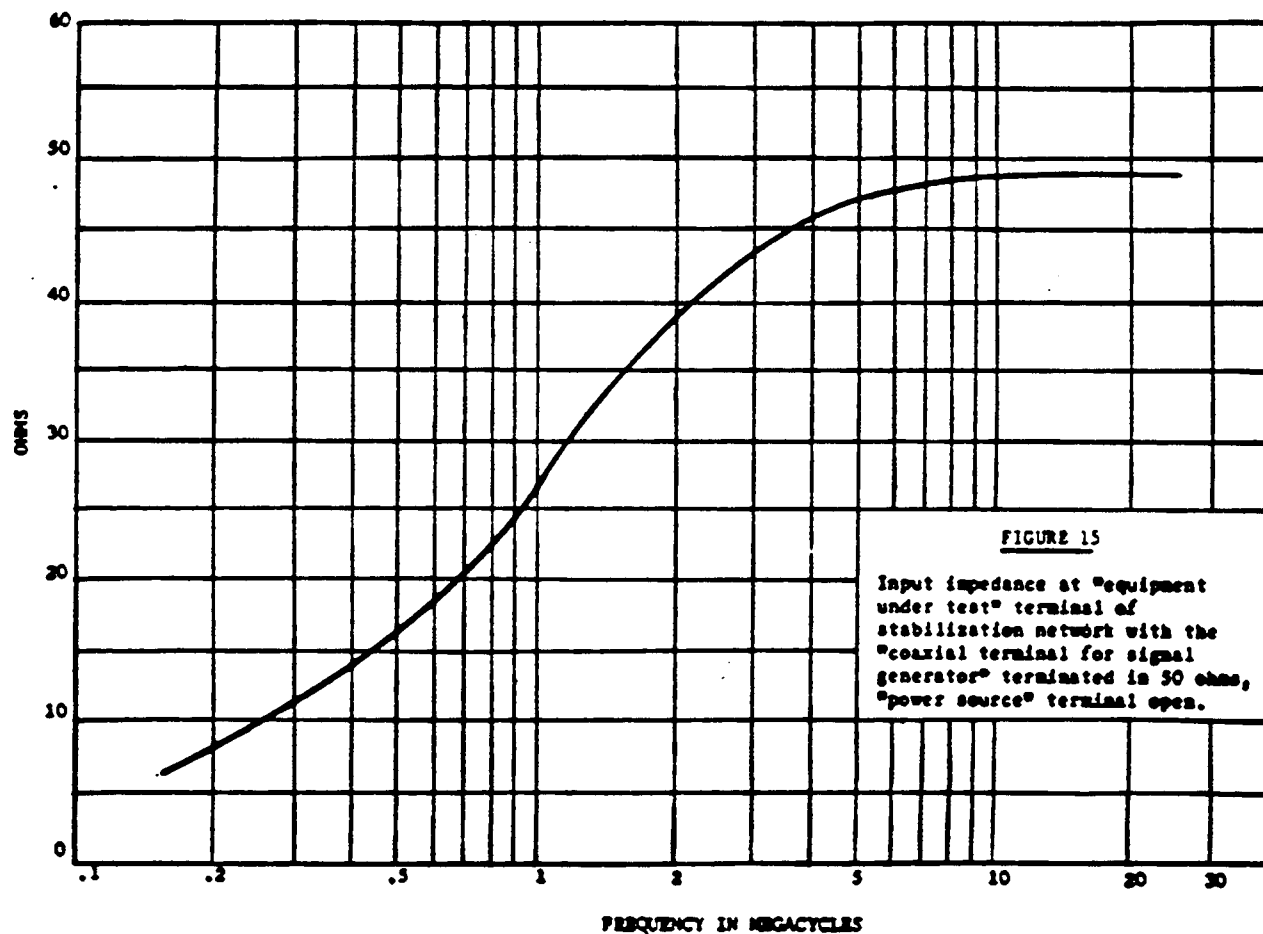
CAPACITOR: C1 SHALL BE MOUNTED ON 1 IN. INSULATING BLOCK ABOVE GROUND.

CAPACITOR DATA: C1=.1 UF, 600-VOLT DC, BATHTUB.

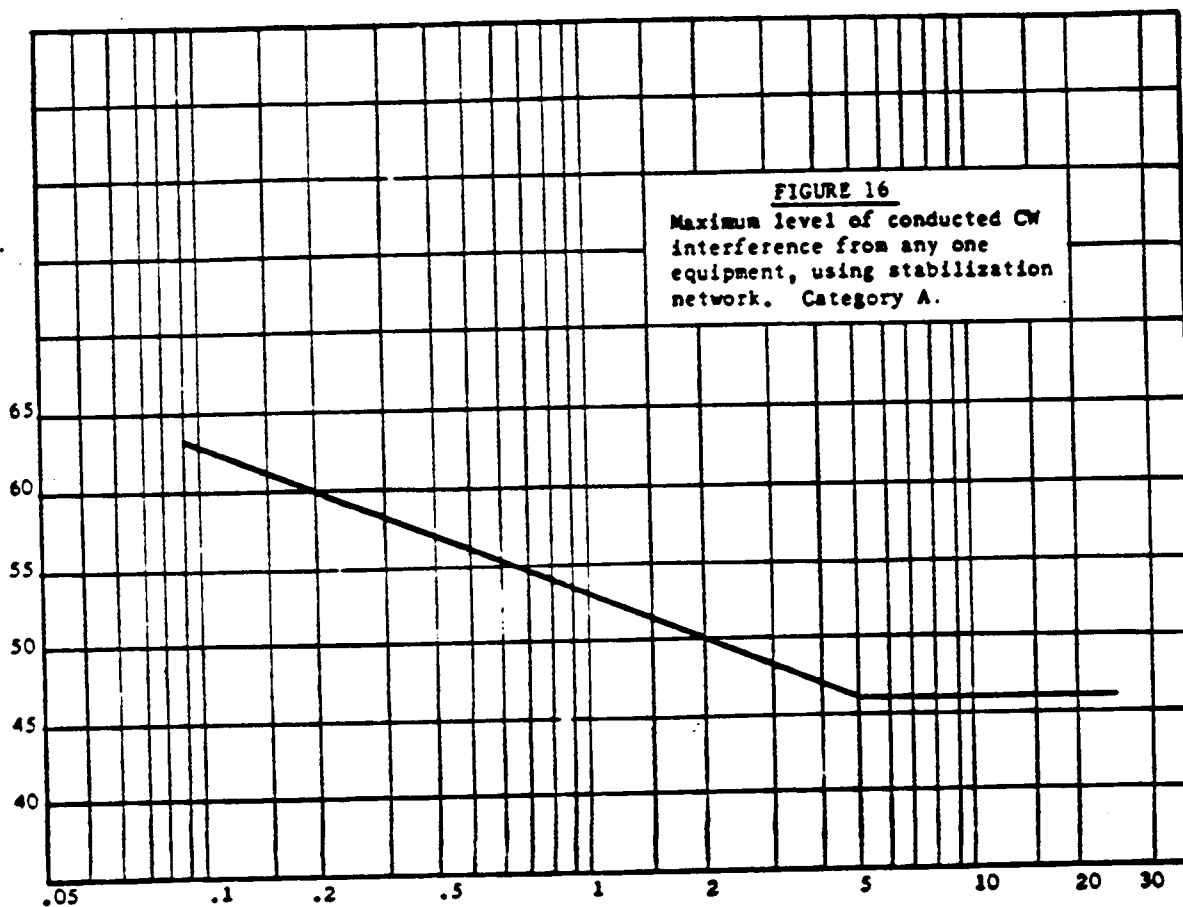
C2=1 UF, 600-VOLT DC, BATHTUB, SINGLE TERMINAL CASE MOUNTED ON GROUND.

RESISTOR DATA: R1=5,000-OHM, 5-WATT CARBON.

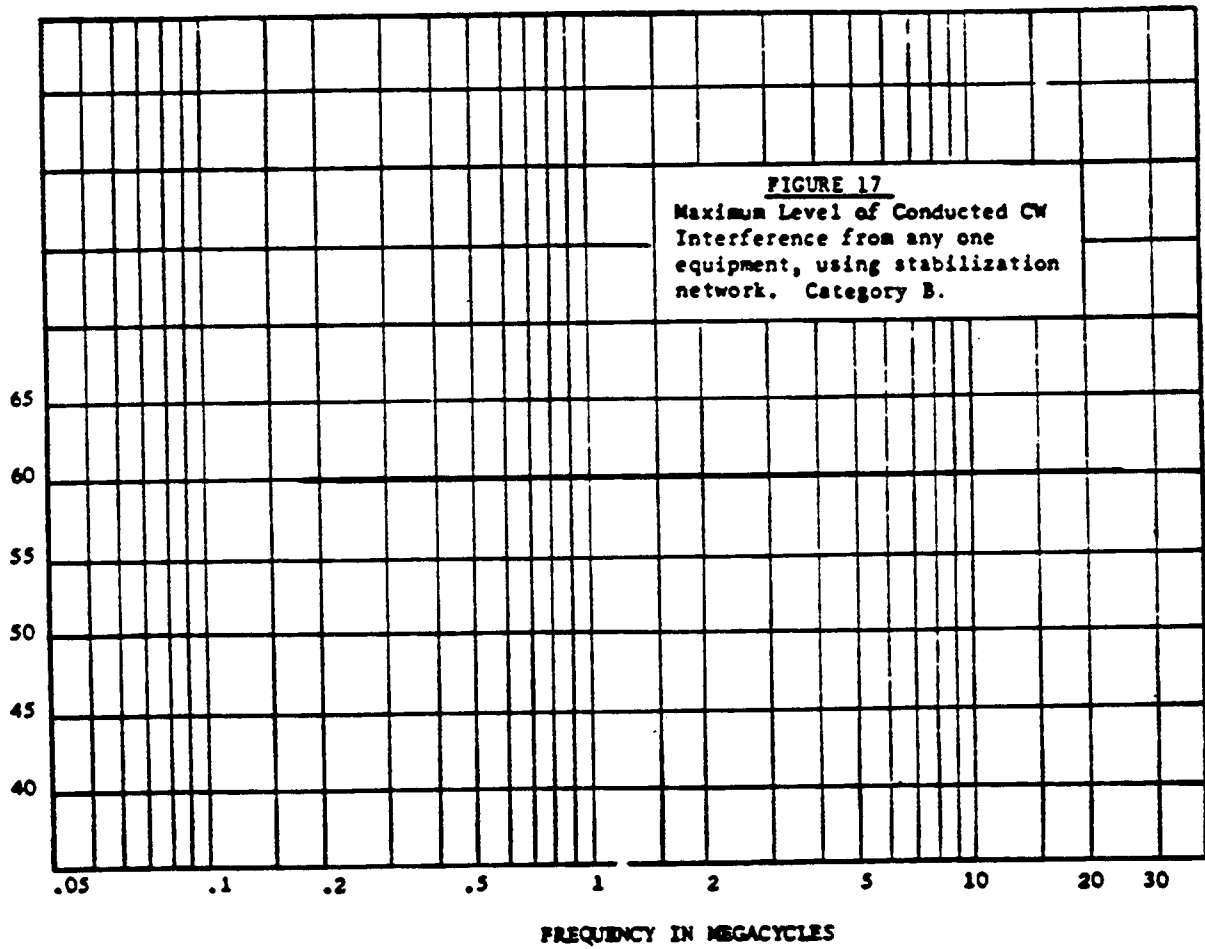
1. The values given for the component parts of the network are nominal. Regardless of the construction or deviation from nominal values, the network must have an impedance within 20 percent of that given in Figure 15.
2. Connecting leads to condensers and resistors should be as nearly as possible to zero length.
3. Networks may also be constructed having a 1-ohm series resistor between the line and capacitor C2. This 1-ohm resistor shall be made up from ten 10-ohm, 1-watt composition resistors.
4. The data given in this figure is suitable for the construction of 50-ampere networks. Other current-carrying networks may be constructed by changing the wire size given for the coil and the size of the over-all enclosure.
5. The 50-ohm transmission line should be extended within the enclosure right up to the location where it connects with capacitor C1.



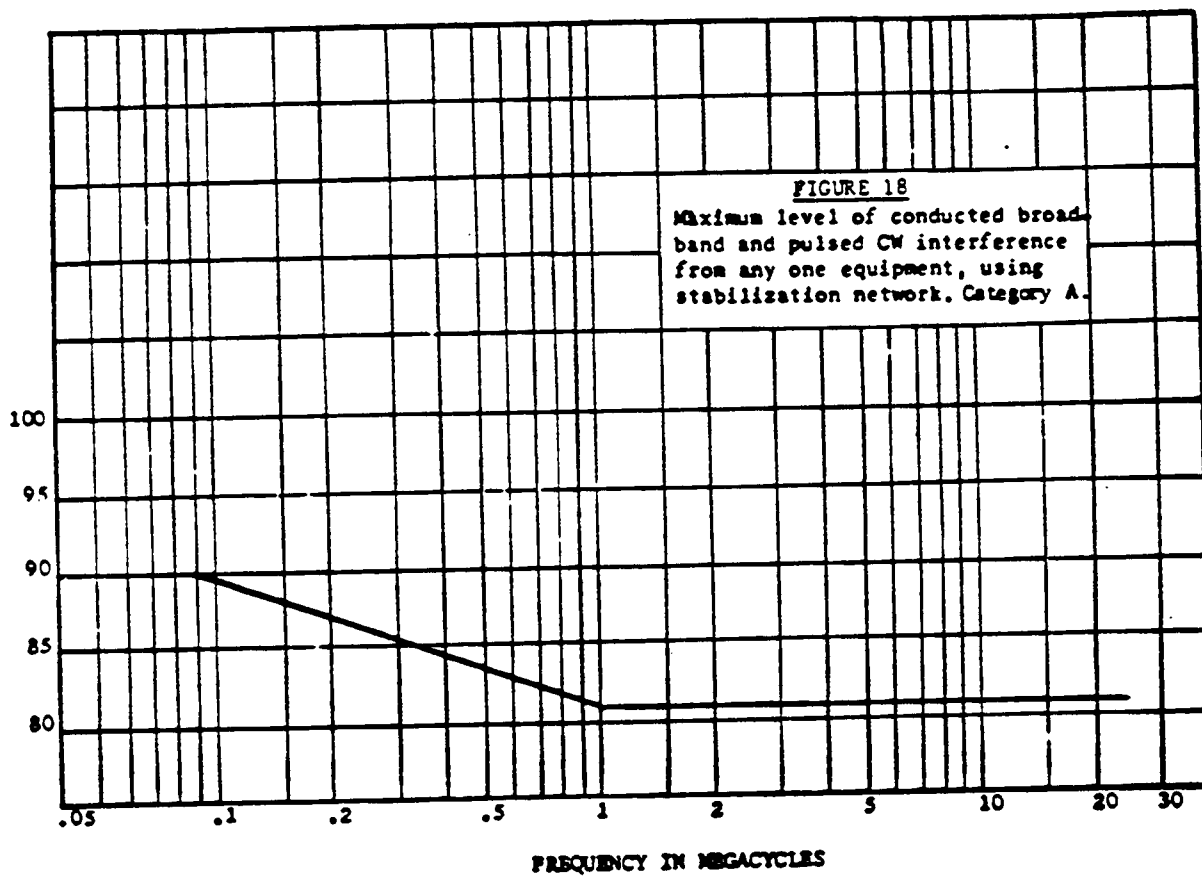
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK



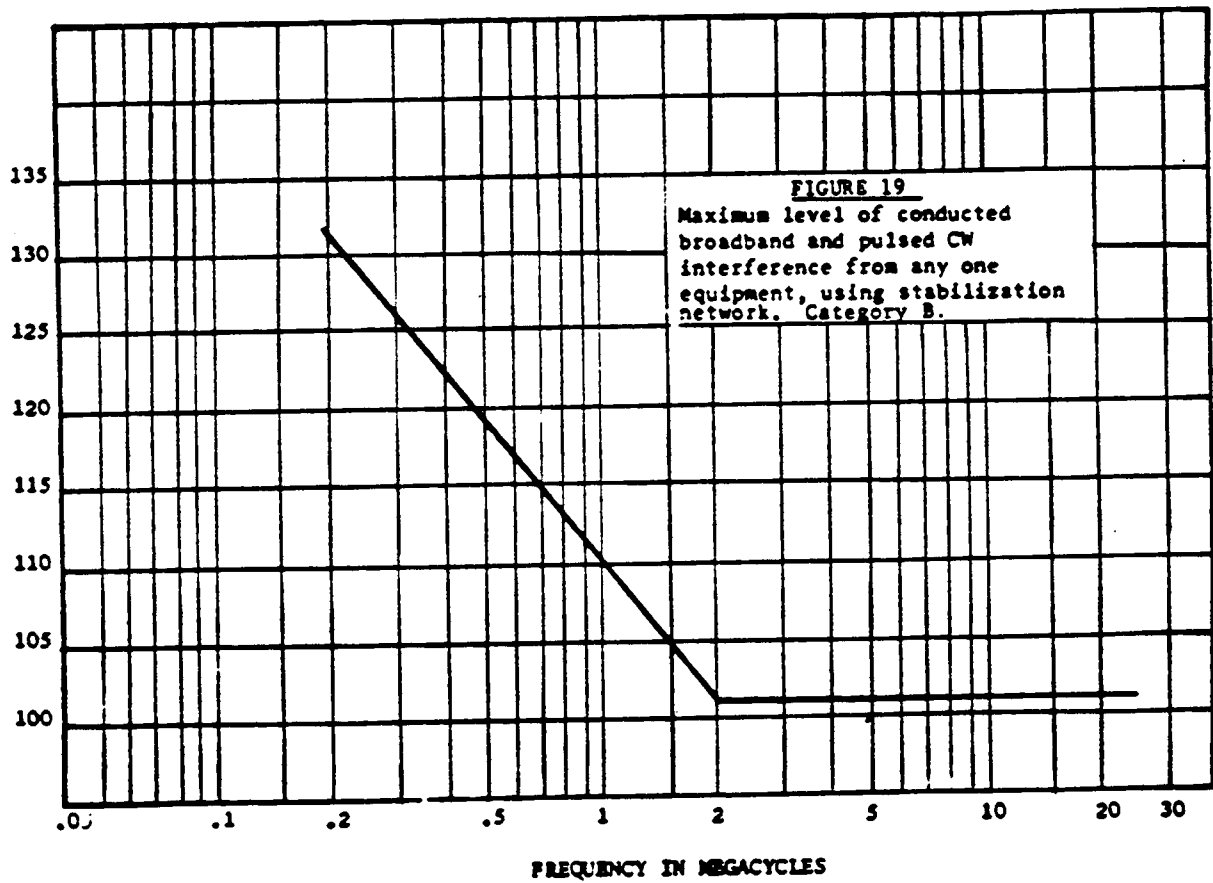
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK

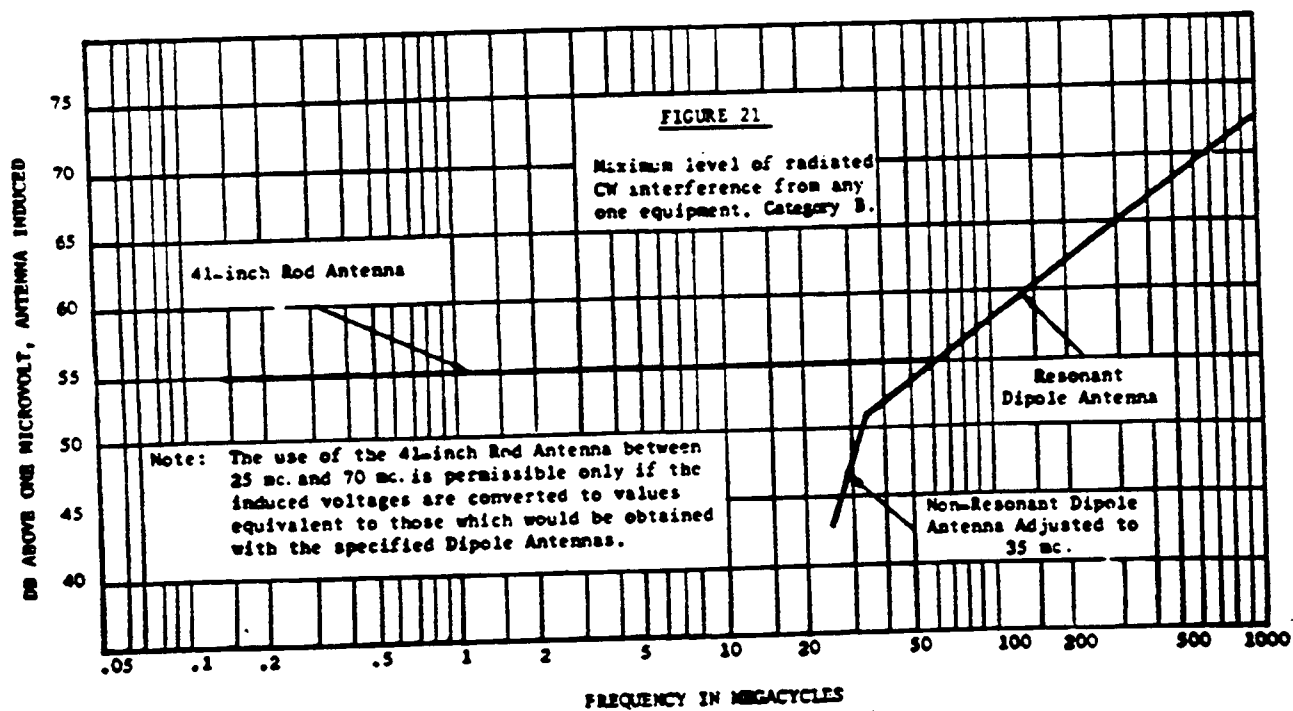
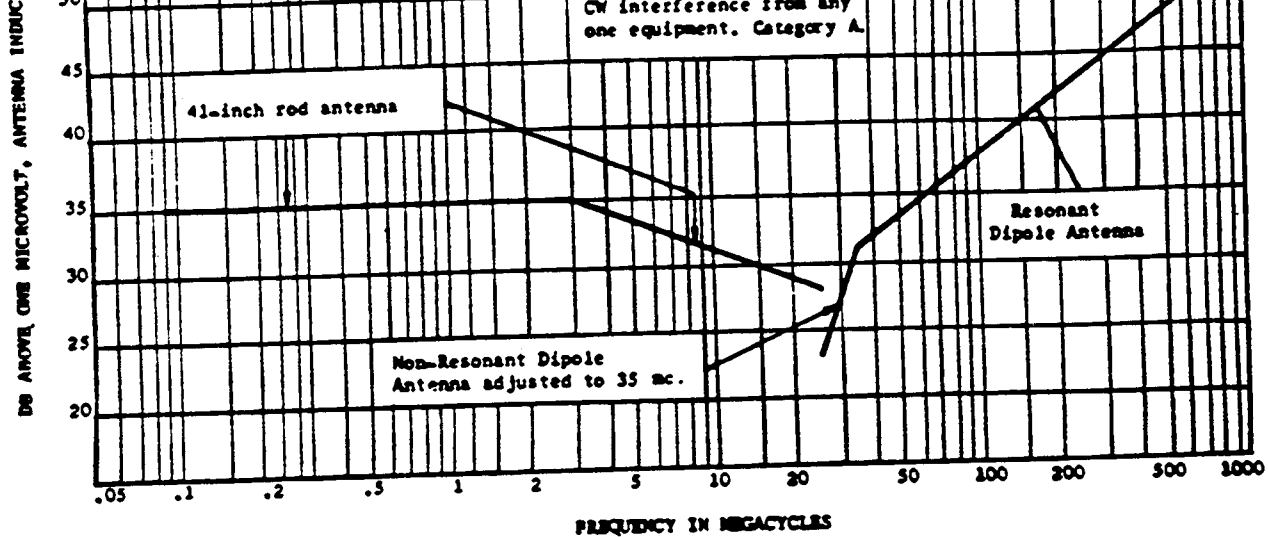


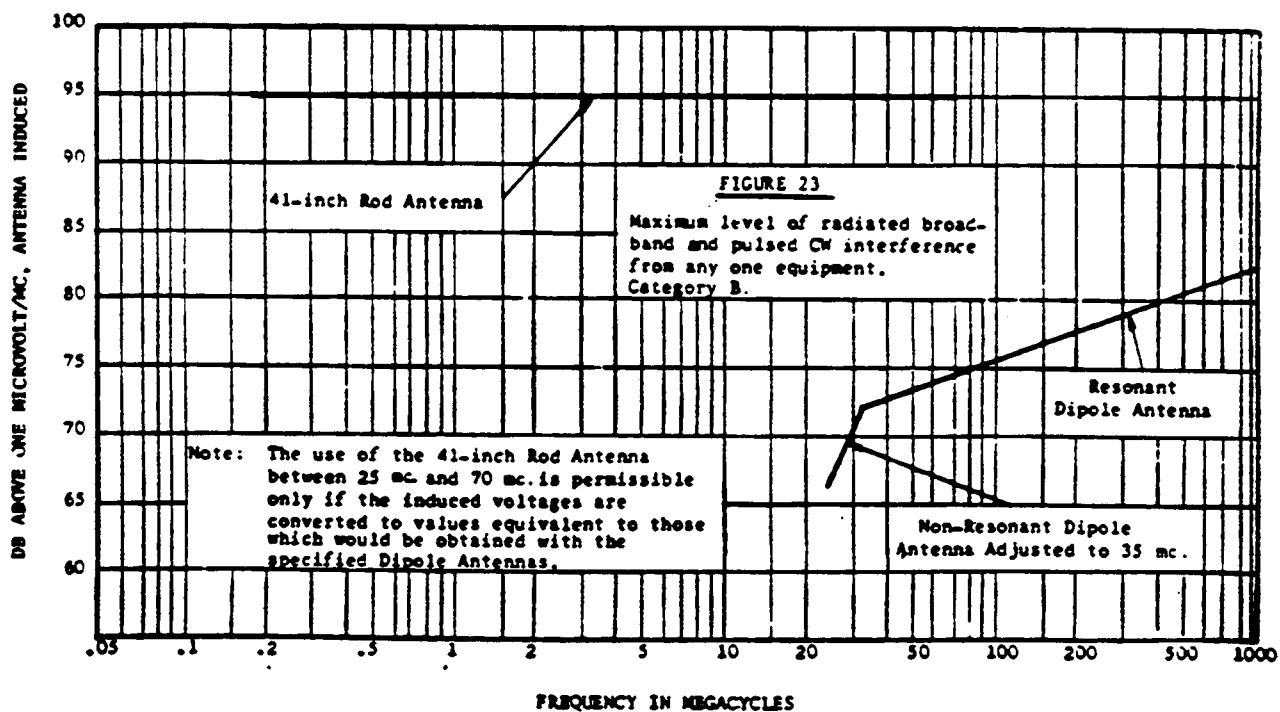
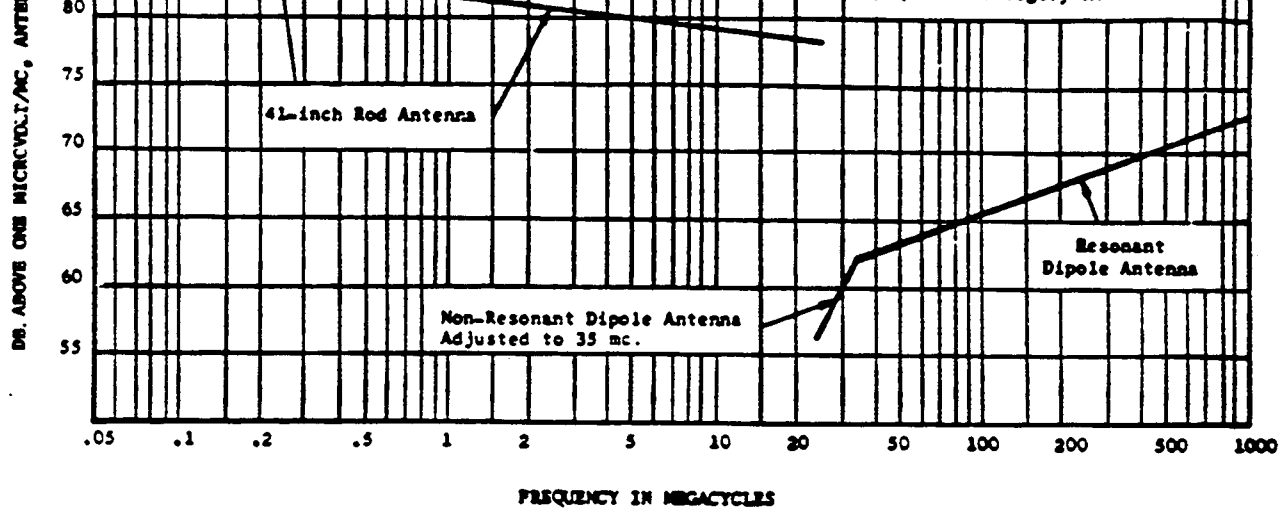
DB ABOVE ONE MICROVOLT/MC AT INPUT TO LINE STABILIZATION NETWORK

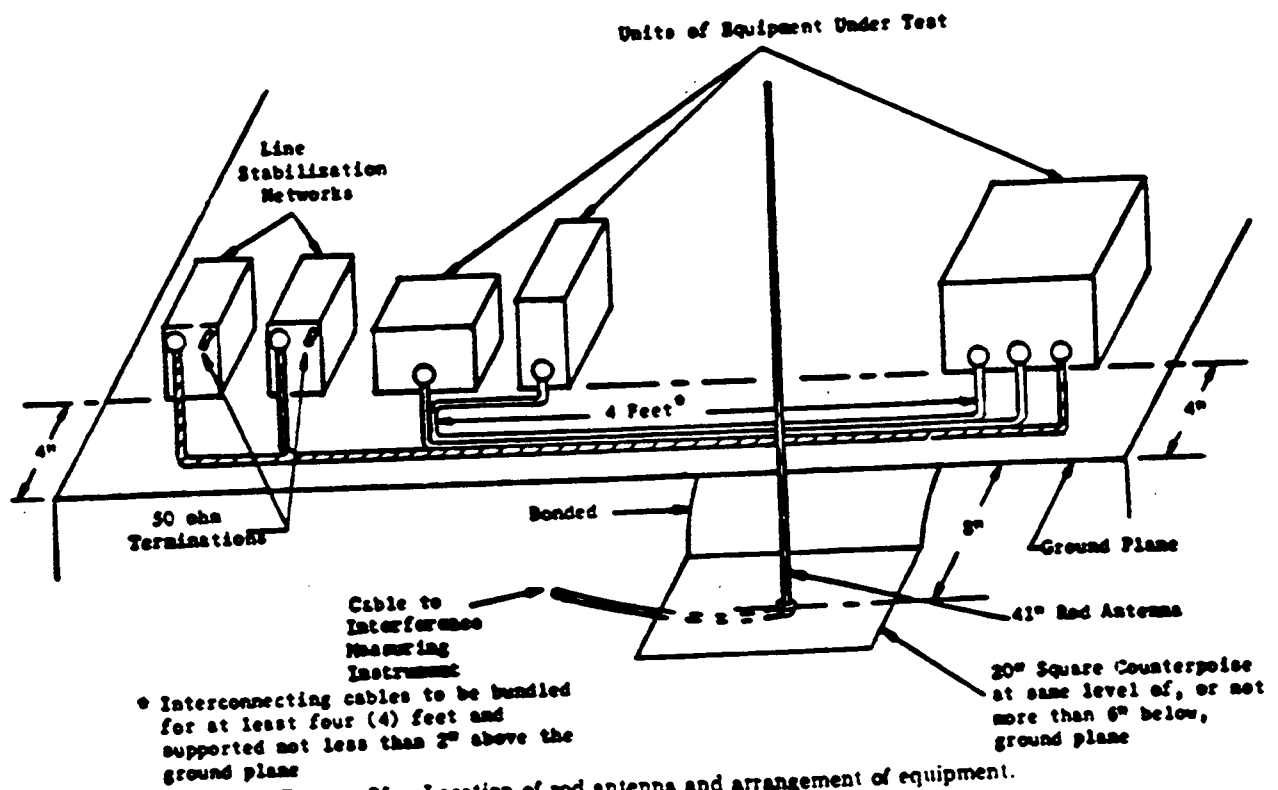
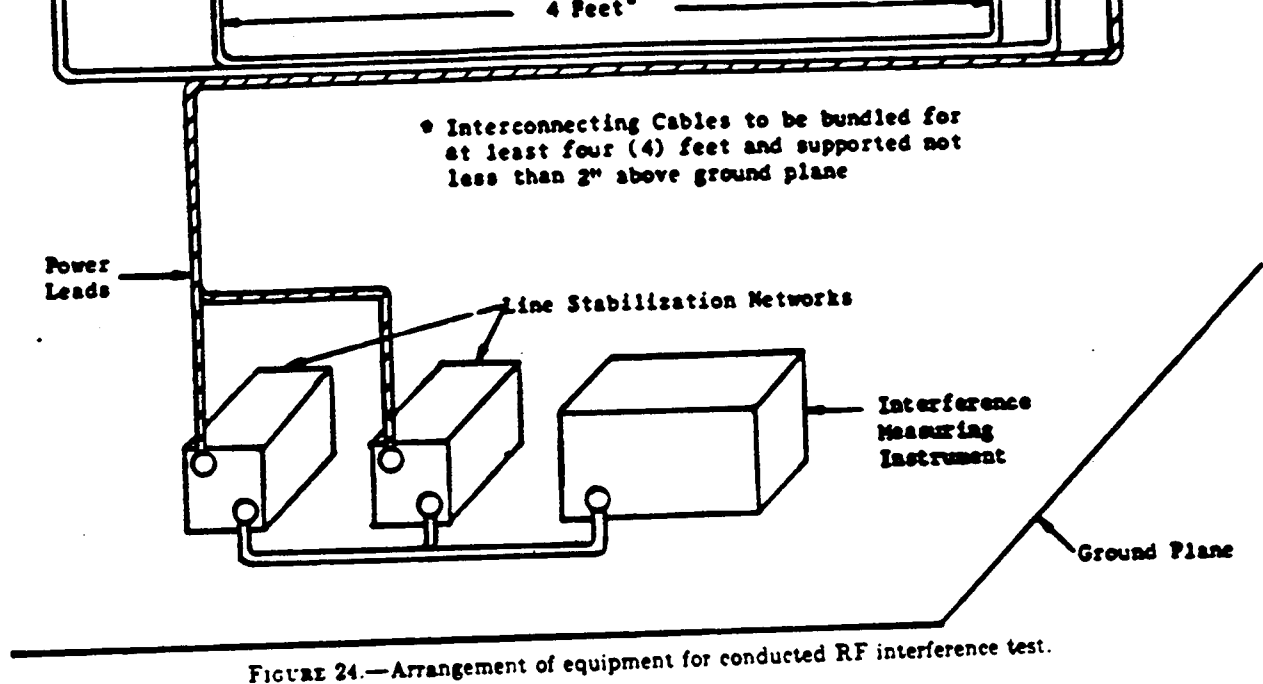


DB ABOVE ONE MICROWATT/MC AT INPUT TO LINE STABILIZATION NETWORK









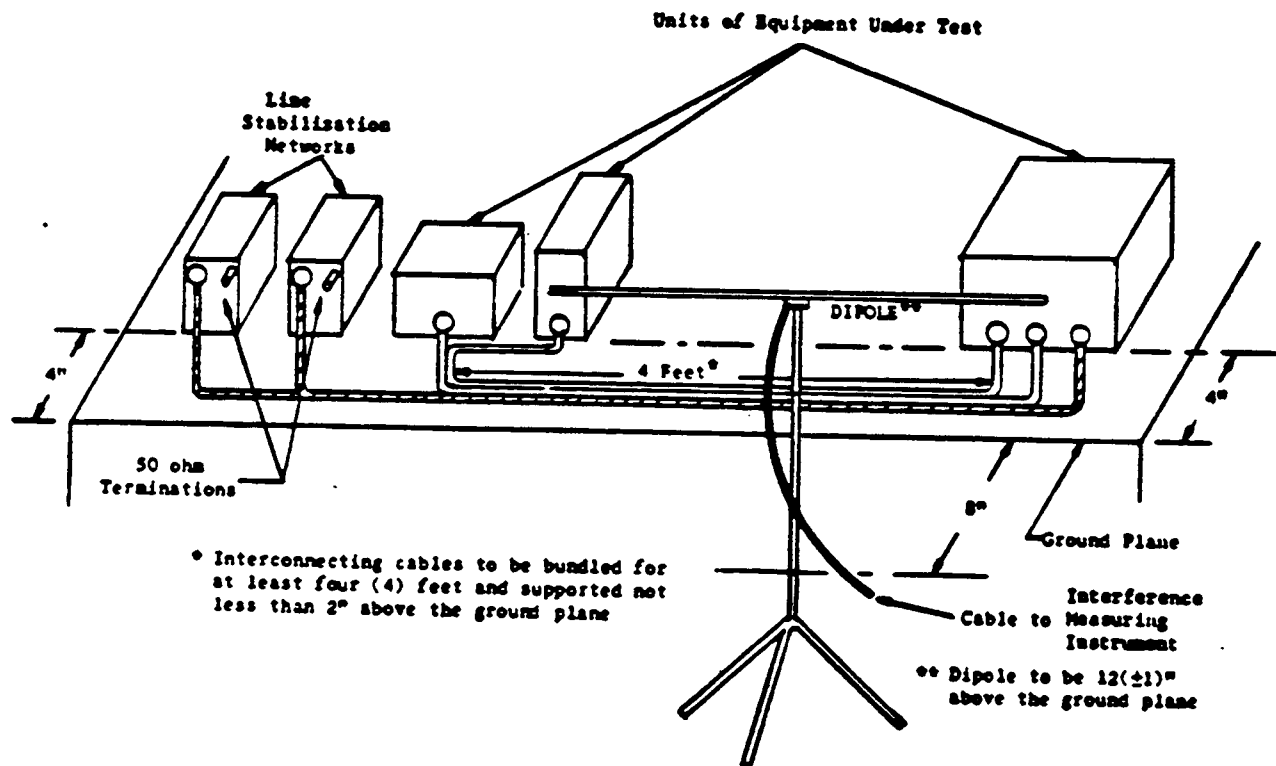


FIGURE 26.—Location of dipole antenna and arrangement of equipment.

